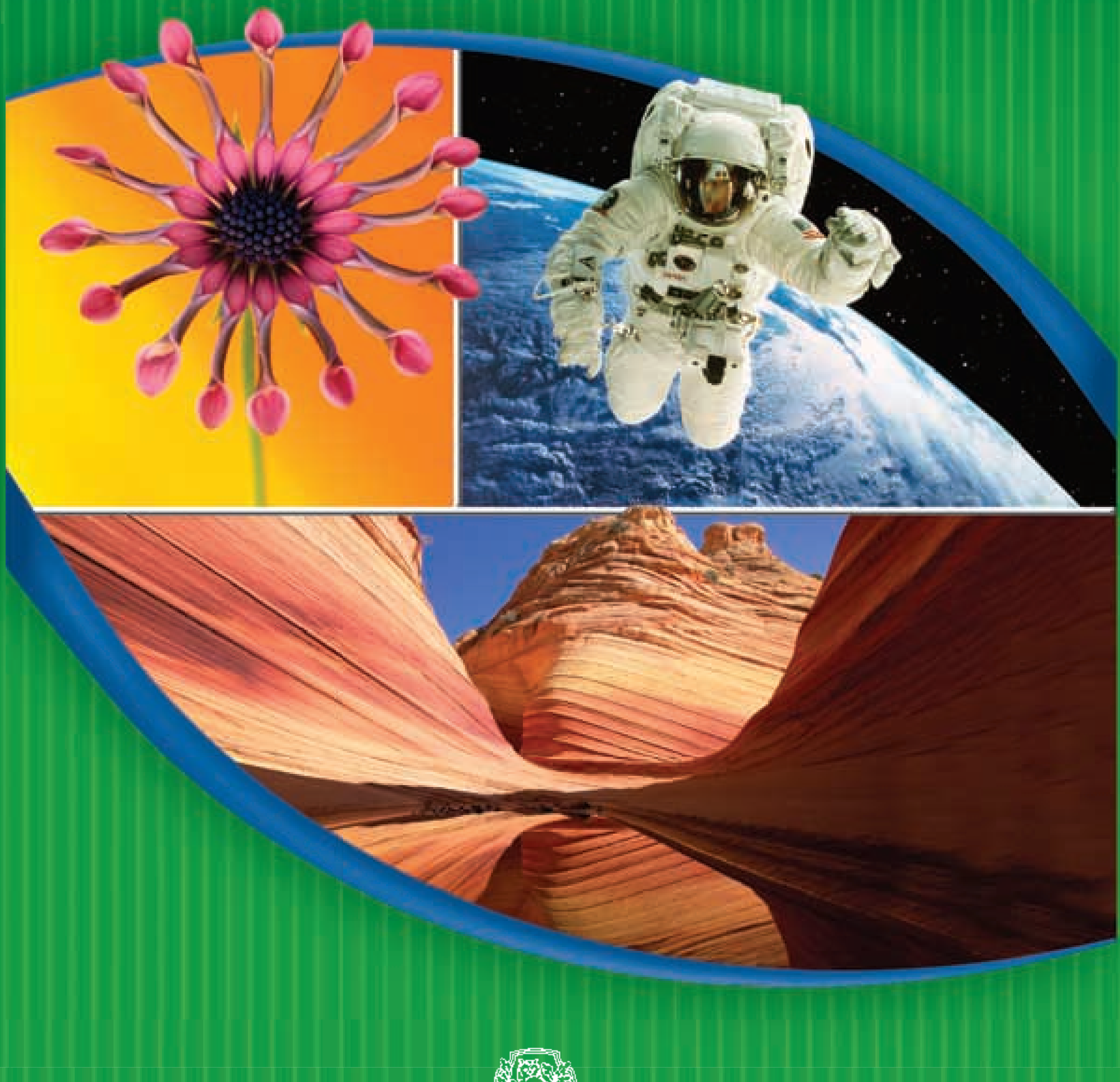
North Carolina

grade 6

HOLT SCIENCE & TECHNOLOGY



HOLT, RINEHART AND WINSTON

A Harcourt Education Company

Orlando • **Austin** • New York • San Diego • Toronto • London

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Acknowledgments

Contributing Authors

Katy Z. Allen
Science Writer
Wayland, Massachusetts

Linda Ruth Berg, Ph.D.
Adjunct Professor
Natural Sciences
St. Petersburg College
St. Petersburg, Florida

Kathleen Meehan Berry
Science Chairman
Canon-McMillan School District
Canonsburg, Pennsylvania

Leila Dumas
Former Physics Teacher
Austin, Texas

Robert H. Fronk, Ph.D.
Professor
Science and Mathematics Education Department
Florida Institute of Technology
Melbourne, Florida

Mary Kay Hemenway, Ph.D.
Research Associate and Senior Lecturer
Department of Astronomy
The University of Texas at Austin
Austin, Texas

Kathleen Kaska
Former Life and Earth Science Teacher and Science Department Chair

William G. Lamb, Ph.D.
Winningstad Chair in the Physical Sciences
Oregon Episcopal School
Portland, Oregon

Peter E. Malin, Ph.D.
Professor of Geology
Division of Earth and Ocean Sciences
Duke University
Durham, North Carolina

Karen J. Meech, Ph.D.
Astronomer
Institute for Astronomy
University of Hawaii
Honolulu, Hawaii

Robert J. Sager, M.S., J.D., L.G.
Coordinator and Professor of Earth Science
Pierce College
Lakewood, Washington

North Carolina Teacher Consultants

Pamela B. Heath
Director of Middle Grades Education
Lenoir County Public Schools
Kinston, North Carolina

James Thomas Heldreth III
Science Teacher
Eastern Guilford Middle School
Gibsonville, North Carolina

Brian Herndon
Instructional Specialist
Gaston County Schools
Gastonia, North Carolina

Dorothea Holley
Teacher
Southwest Middle School
Charlotte, North Carolina

Larry Hollis
Earth and Environmental Science Teacher
Southwest Middle School
Charlotte, North Carolina

Beverly Lyons
Science Teacher and Department Chair
Hanes Middle School
Winston-Salem, North Carolina

Donna Roberts
Science Teacher
Concord Middle School
Concord, North Carolina

Patricia Sherron-Underwood
K–8 Math and Science Curriculum Specialist
Curriculum and Instruction Department
Randolph County School District
Asheboro, North Carolina

Carolyn Woolsey
Science Teacher
Southwest Middle School
Charlotte, North Carolina

Inclusion Specialists

Karen Clay
Inclusion Specialist Consultant
Boston, Massachusetts

Ellen McPeek Glisan
Special Needs Consultant
San Antonio, Texas

Safety Reviewer

Jack Gerlovich, Ph.D.
Associate Professor
School of Education
Drake University
Des Moines, Iowa

Academic Reviewers

Glenn Adelson
Instructor
Biology Undergraduate Program
Harvard University
Cambridge, Massachusetts

David M. Armstrong, Ph.D.
Professor
Ecology and Evolutionary Biology
University of Colorado
Boulder, Colorado

Kenneth H. Brink, Ph.D.
Senior Scientist and Physical Oceanography Director
Coastal Ocean Institute and Rinehart Coastal Research Center
Woods Hole Oceanographic Institution
Woods Hole, Massachusetts

Acknowledgments
continued on page 747

Copyright © 2005 by Holt, Rinehart and Winston

All rights reserved. No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopy, recording, or any information storage and retrieval system, without permission in writing from the publisher.

Requests for permission to make copies of any part of the work should be mailed to the following address: Permissions Department, Holt, Rinehart and Winston, 10801 N. MoPac Expressway, Building 3, Austin, Texas 78759.

CNN is a registered trademark and **CNN STUDENT NEWS** is a trademark of Cable News Network LP, LLLP, an AOL Time Warner Company.

Current Science is a registered trademark of Weekly Reader Corporation.

The **SciLinks** trademark and service are owned and provided by the National Science Teachers Association. All rights reserved.

Printed in the United States of America

ISBN 0-03-021282-0

1 2 3 4 5 6 7 048 08 07 06 05 04

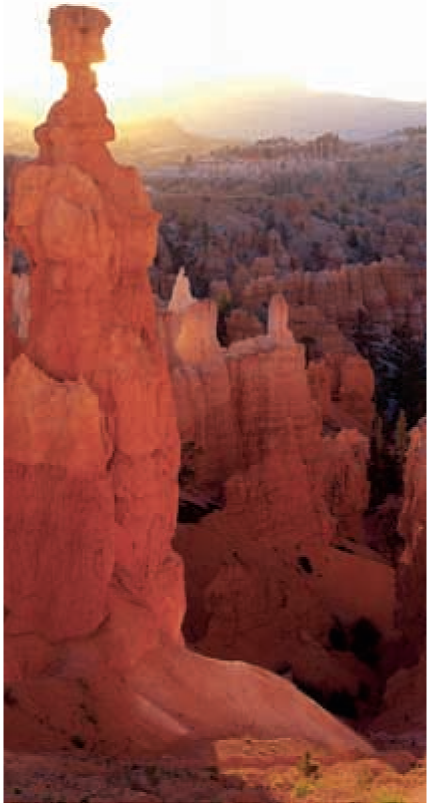
Copyright © by Holt, Rinehart and Winston. All rights reserved.

Contents in Brief

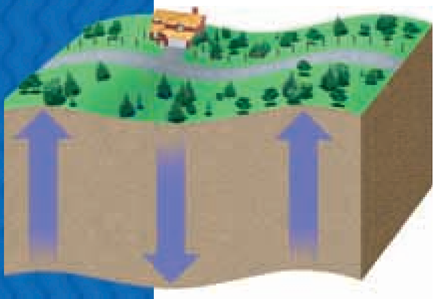
Copyright © by Holt, Rinehart and Winston. All rights reserved.

Contents

Copyright © by Holt, Rinehart and Winston. All rights reserved.



Copyright © by Holt, Rinehart and Winston. All rights reserved.

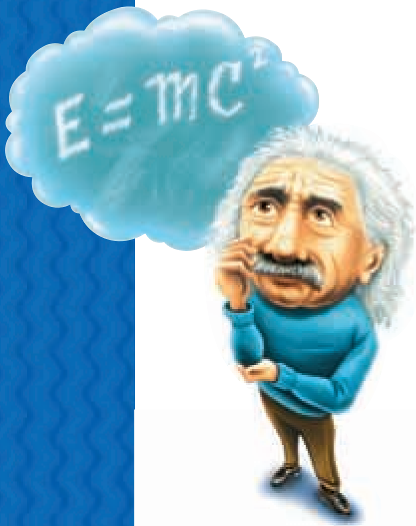


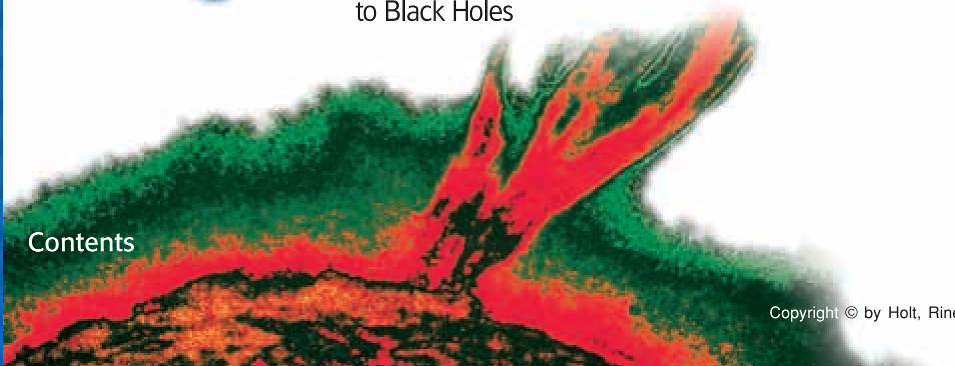
Copyright © by Holt, Rinehart and Winston. All rights reserved.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

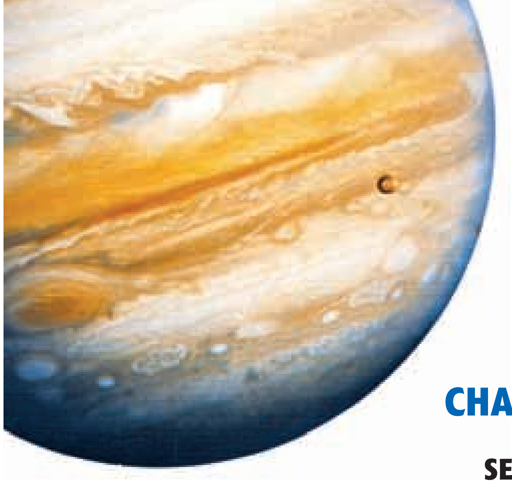
UNIT 3 Our Solar System







Copyright © by Holt, Rinehart and Winston. All rights reserved.

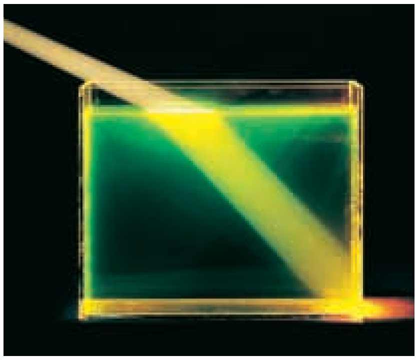


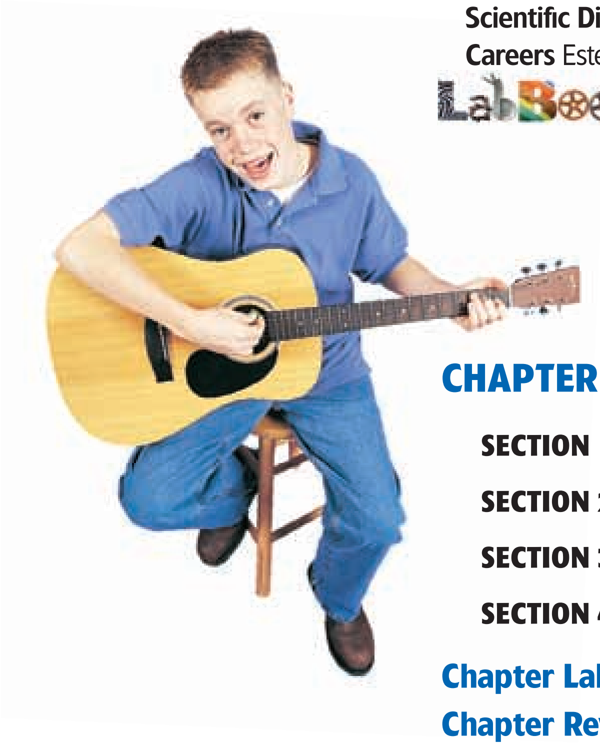
Copyright © by Holt, Rinehart and Winston. All rights reserved.

UNIT 4 Energy on the Move

Copyright © by Holt, Rinehart and Winston. All rights reserved.

UNIT 5 Waves, Sound, and Light

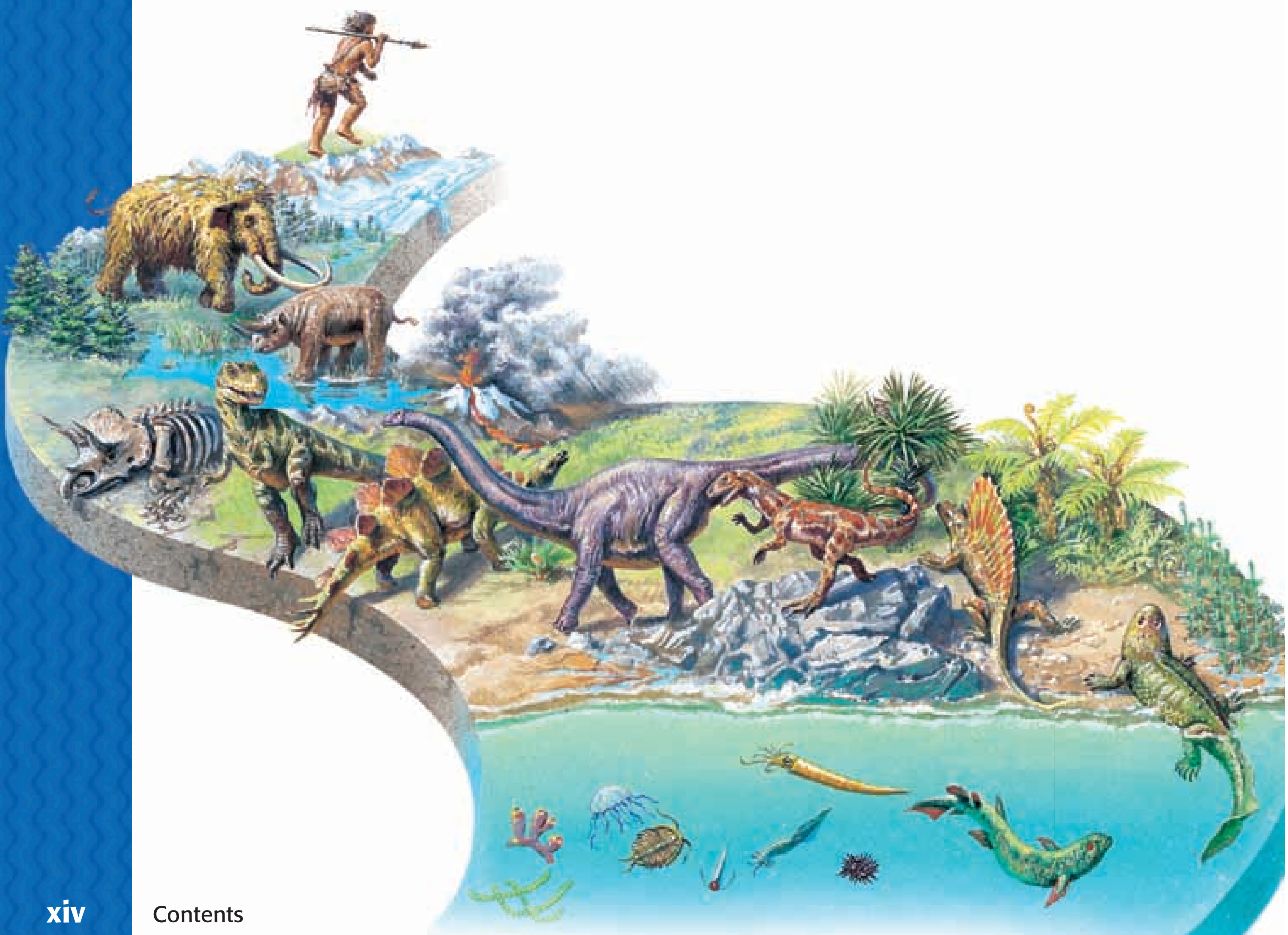




Copyright © by Holt, Rinehart and Winston. All rights reserved.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Copyright © by Holt, Rinehart and Winston. All rights reserved.



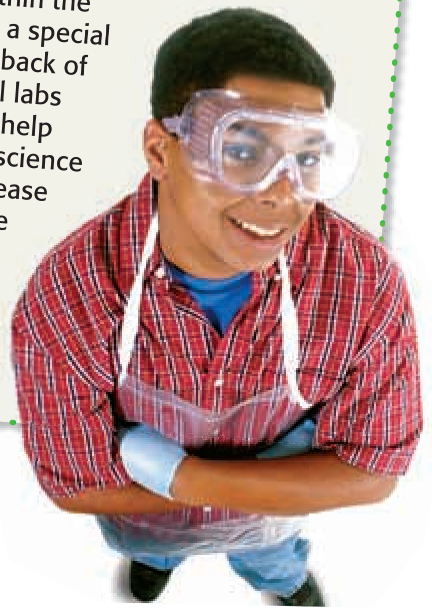
Copyright © by Holt, Rinehart and Winston. All rights reserved.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Chapter Labs and LabBook

The more labs, the better!

Take a minute to browse the variety of exciting **labs** in this textbook. Labs appear within the chapters and in a special LabBook in the back of the textbook. All labs are designed to help you experience science firsthand. But please don't forget to be safe. Read the Safety First! section before starting any of the labs.



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Start your engines with an activity!

Get motivated to learn by doing the two activities at the beginning of each chapter. The **Pre-Reading Activity** helps you organize information as you read the chapter. The **Start-up Activity** helps you gain scientific understanding of the topic through hands-on experience.

PRE-READING ACTIVITY

FOLDNOTES

Graphic Organizer

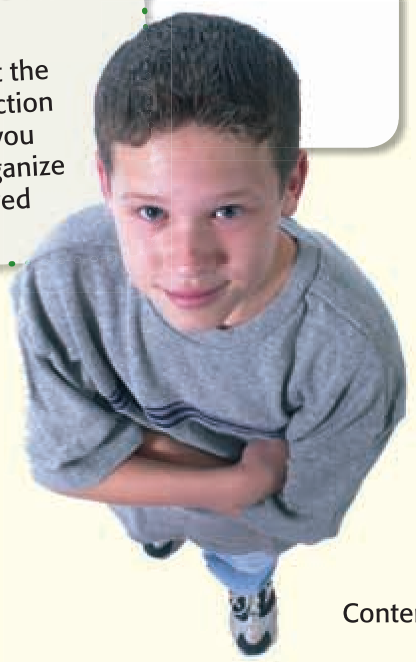
START-UP ACTIVITY

Copyright © by Holt, Rinehart and Winston. All rights reserved.

READING STRATEGY

Remembering what you read doesn't have to be hard!

A **Reading Strategy** at the beginning of every section provides tips to help you remember and/or organize the information covered in the section.



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Quick Lab

School to Home

Activity

Science brings you closer together!

Bring science into your home by doing **School-to-Home Activities** with a parent or another adult in your household.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Internet Activity

Get caught in the Web!

Go to **go.hrw.com** for **Internet Activities** related to each chapter. To find the Internet Activity for a particular chapter, just type in the keyword listed below.

Math Practice

Math Focus

Science and math go hand in hand.

The **Math Focus** and **Math Practice** items show you many ways that math applies directly to science and vice versa.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Connection to...

One subject leads to another.

You may not realize it at first, but different subjects are related to each other in many ways. Each **Connection** explores a topic from the viewpoint of another discipline. In this way, all of the subjects you learn about in school merge to improve your understanding of the world around you.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Science in Action

Careers

People in Science

Science, Technology, and Society

Science moves beyond the classroom!

Read **Science in Action** articles to learn more about science in the real world. These articles will give you an idea of how interesting, strange, helpful, and action-packed science is. At the end of each chapter, you will find three short articles. And if your thirst is still not quenched, go to **go.hrw.com** for in-depth coverage.

Scientific Debate

Scientific Discoveries

Weird Science

Science Fiction

Copyright © by Holt, Rinehart and Winston. All rights reserved.

How to Use Your Textbook

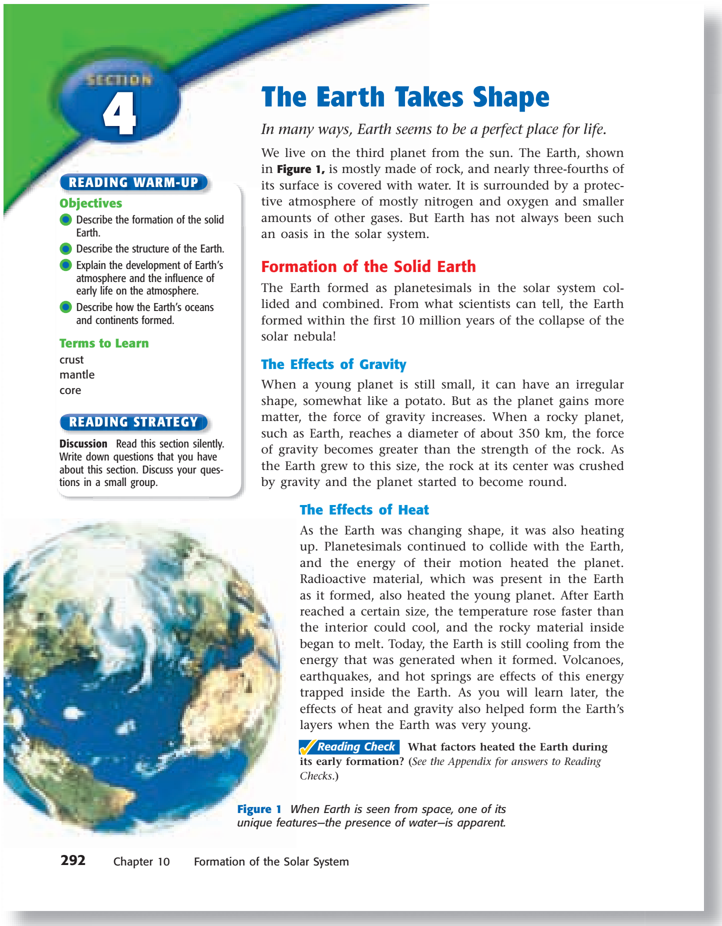
Your Roadmap for Success with Holt Science and Technology

Reading Warm-Up

A Reading Warm-Up at the beginning of every section provides you with the section's objectives and key terms. The objectives tell you what you'll need to know after you finish reading the section.

Key terms are listed for each section. Learn the definitions of these terms because you will most likely be tested on them. Each key term is highlighted in the text and is defined at point of use and in the margin. You can also use the glossary to locate definitions quickly.

STUDY TIP Reread the objectives and the definitions to the key terms when studying for a test to be sure you know the material.



SECTION 4

READING WARM-UP

Objectives

- Describe the formation of the solid Earth.
- Describe the structure of the Earth.
- Explain the development of Earth's atmosphere and the influence of early life on the atmosphere.
- Describe how the Earth's oceans and continents formed.

Terms to Learn

crust
mantle
core

READING STRATEGY

Discussion Read this section silently. Write down questions that you have about this section. Discuss your questions in a small group.

The Earth Takes Shape

In many ways, Earth seems to be a perfect place for life.

We live on the third planet from the sun. The Earth, shown in **Figure 1,** is mostly made of rock, and nearly three-fourths of its surface is covered with water. It is surrounded by a protective atmosphere of mostly nitrogen and oxygen and smaller amounts of other gases. But Earth has not always been such an oasis in the solar system.

Formation of the Solid Earth

The Earth formed as planetesimals in the solar system collided and combined. From what scientists can tell, the Earth formed within the first 10 million years of the collapse of the solar nebula!

The Effects of Gravity

When a young planet is still small, it can have an irregular shape, somewhat like a potato. But as the planet gains more matter, the force of gravity increases. When a rocky planet, such as Earth, reaches a diameter of about 350 km, the force of gravity becomes greater than the strength of the rock. As the Earth grew to this size, the rock at its center was crushed by gravity and the planet started to become round.

The Effects of Heat

As the Earth was changing shape, it was also heating up. Planetesimals continued to collide with the Earth, and the energy of their motion heated the planet. Radioactive material, which was present in the Earth as it formed, also heated the young planet. After Earth reached a certain size, the temperature rose faster than the interior could cool, and the rocky material inside began to melt. Today, the Earth is still cooling from the energy that was generated when it formed. Volcanoes, earthquakes, and hot springs are effects of this energy trapped inside the Earth. As you will learn later, the effects of heat and gravity also helped form the Earth's layers when the Earth was very young.

Reading Check What factors heated the Earth during its early formation? (*See the Appendix for answers to Reading Checks.*)

Figure 1 *When Earth is seen from space, one of its unique features—the presence of water—is apparent.*

292 Chapter 10 Formation of the Solar System

Get Organized

A Reading Strategy at the beginning of every section provides tips to help you organize and remember the information covered in the section. Keep a science notebook so that you are ready to take notes when your teacher reviews the material in class. Keep your assignments in this notebook so that you can review them when studying for the chapter test.

Be Resourceful—Use the Web

SciLinks®

Internet Connect boxes in your textbook take you to resources that you can use for science projects, reports, and research papers. Go to scilinks.org, and type in the SciLinks code to get information on a topic.

go.hrw.com

Visit go.hrw.com Find worksheets, **Current Science®** magazine articles online, and other materials that go with your textbook at **go.hrw.com.** Click on the textbook icon and the table of contents to see all of the resources for each chapter.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

How the Earth's Layers Formed

Have you ever watched the oil separate from vinegar in a bottle of salad dressing? The vinegar sinks because it is denser than oil. The Earth's layers formed in much the same way. As rocks melted, denser materials, such as nickel and iron, sank to the centre of the Earth and formed the core. Less dense materials floated to the surface and became the crust. This process is shown in **Figure 1.**

The **crust** is the thin, outermost layer of the Earth. It is 5 to 100 km thick. Crustal rock is made of materials that have low densities, such as oxygen, silicon, and aluminum. The **mantle** is the layer of Earth beneath the crust. It extends 2,900 km below the surface. Mantle rock is made of materials such as magnesium and iron and is denser than crustal rock. The **core** is the central part of the Earth below the mantle. It contains the densest materials (nickel and iron) and extends to the centre of the Earth—almost 6,400 km below the surface.

crust the thin and solid outermost layer of the Earth above the mantle

mantle the layer of rock between the Earth's crust and core

core the central part of the Earth below the mantle

Figure 1 The Formation of Earth's Layers

1 All materials in the early Earth are randomly mixed.

2 Rocks melt, and denser materials sink toward the center. Less dense elements rise and form layers.

3 According to composition, the Earth is divided into three layers: the crust, the mantle, and the core.

Crust

Mantle

The Growth of Continents

After a while, some of the rocks were light enough to pile up on the surface. These rocks were the beginning of the earliest continents. The continents gradually thickened and slowly rose above the surface of the ocean. These scattered young continents did not stay in the same place, however. The slow transfer of thermal energy in the mantle pushed them around. Approximately 2.5 billion years ago, continents really started to grow. And by 1.5 billion years ago, the upper mantle had cooled and had become denser and heavier. At this time, it was easier for the cooler parts of the mantle to sink. These conditions made it easier for the continents to move in the same way that they do today.

INTERNET ACTIVITY

For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HZ5SOLW.**

SECTION Review

Summary

- The effects of gravity and heat created the shape and structure of Earth.
- The Earth is divided into three main layers based on composition: the crust, mantle, and core.
- The presence of life dramatically changed Earth's atmosphere by adding free oxygen.
- Earth's oceans formed shortly after the Earth did, when it had cooled off enough for rain to fall. Continents formed when lighter materials gathered on the surface and rose above sea level.

Using Key Terms

1. Use each of the following terms in a separate sentence: *crust, mantle,* and *core.*

Understanding Key Ideas

2. Earth's first atmosphere was mostly made of
 a. nitrogen and oxygen.
 b. chlorine, nitrogen, and sulfur.
 c. carbon dioxide and water vapor.
 d. water vapor and oxygen.
3. Describe the structure of the Earth.
4. Why did the Earth separate into distinct layers?
5. Describe the development of Earth's atmosphere. How did life affect Earth's atmosphere?
6. Explain how Earth's oceans and continents formed.

Critical Thinking

7. **Applying Concepts** How did the effects of gravity help shape the Earth?
8. **Making Inferences** How would the removal of forests affect the Earth's atmosphere?

Interpreting Graphics

Use the illustration below to answer the questions that follow.

a b c

9. Which of the layers is composed mostly of the elements magnesium and iron?
10. Which of the layers is composed mostly of the elements iron and nickel?

SCiLINKS. NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: The Layers of the Earth; The Oceans
SciLinks code: HSM0862; HSM1069

297

Use the Illustrations and Photos

Art shows complex ideas and processes. Learn to analyze the art so that you better understand the material you read in the text.

Tables and graphs display important information in an organized way to help you see relationships.

A picture is worth a thousand words. Look at the photographs to see relevant examples of science concepts that you are reading about.

Answer the Section Reviews

Section Reviews test your knowledge of the main points of the section. Critical Thinking items challenge you to think about the material in greater depth and to find connections that you infer from the text.

STUDY TIP When you can't answer a question, reread the section. The answer is usually there.

Do Your Homework

Your teacher may assign worksheets to help you understand and remember the material in the chapter.

STUDY TIP Don't try to answer the questions without reading the text and reviewing your class notes. A little preparation up front will make your homework assignments a lot easier. Answering the items in the Chapter Review will help prepare you for the chapter test.

Holt Online Learning

Visit Holt Online Learning

If your teacher gives you a special password to log onto the Holt Online Learning site, you'll find your complete textbook on the Web. In addition, you'll find some great learning tools and practice quizzes. You'll be able to see how well you know the material from your textbook.

CNN Student News™

Visit CNN Student News

You'll find up-to-date events in science at **cnnstudentnews.com.**

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Exploring, inventing, and investigating are essential to the study of science. However, these activities can also be dangerous. To make sure that your experiments and explorations are safe, you must be aware of a variety of safety guidelines. You have probably heard of the saying, “It is better to be safe than sorry.” This is particularly true in a science classroom where experiments and explorations are being performed. Being uninformed and careless can result in serious injuries. Don’t take chances with your own safety or with anyone else’s.

The following pages describe important guidelines for staying safe in the science classroom. Your teacher may also have safety guidelines and tips that are specific to your classroom and laboratory. Take the time to be safe.

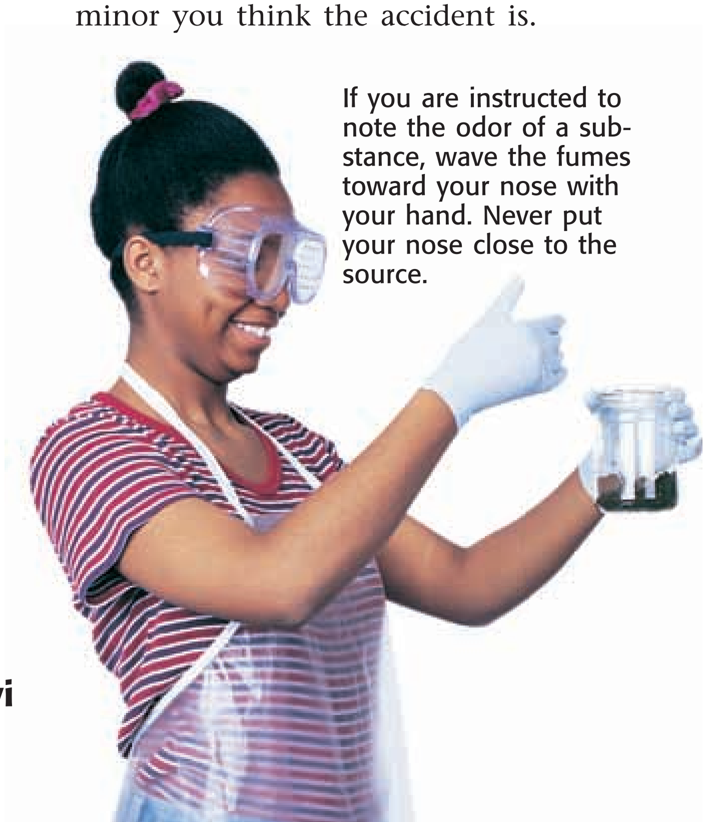
Safety Rules!

Start Out Right

Always get your teacher’s permission before attempting any laboratory exploration. Read the procedures carefully, and pay particular attention to safety information and caution statements. If you are unsure about what a safety symbol means, look it up or ask your teacher. You cannot be too careful when it comes to safety. If an accident does occur, inform your teacher immediately regardless of how minor you think the accident is.

Safety Symbols

All of the experiments and investigations in this book and their related worksheets include important safety symbols to alert you to particular safety concerns. Become familiar with these symbols so that when you see them, you will know what they mean and what to do. It is important that you read this entire safety section to learn about specific dangers in the laboratory.



If you are instructed to note the odor of a substance, wave the fumes toward your nose with your hand. Never put your nose close to the source.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Eye Safety

Wear safety goggles when working around chemicals, acids, bases, or any type of flame or heating device. Wear safety goggles any time there is even the slightest chance that harm could come to your eyes. If any substance gets into your eyes, notify your teacher immediately and flush your eyes with running water for at least 15 minutes. Treat any unknown chemical as if it were a dangerous chemical. Never look directly into the sun. Doing so could cause permanent blindness.

Avoid wearing contact lenses in a laboratory situation. Even if you are wearing safety goggles, chemicals can get between the contact lenses and your eyes. If your doctor requires that you wear contact lenses instead of glasses, wear eye-cup safety goggles in the lab.

Safety Equipment

Know the locations of the nearest fire alarms and any other safety equipment, such as fire blankets and eyewash fountains, as identified by your teacher, and know the procedures for using the equipment.

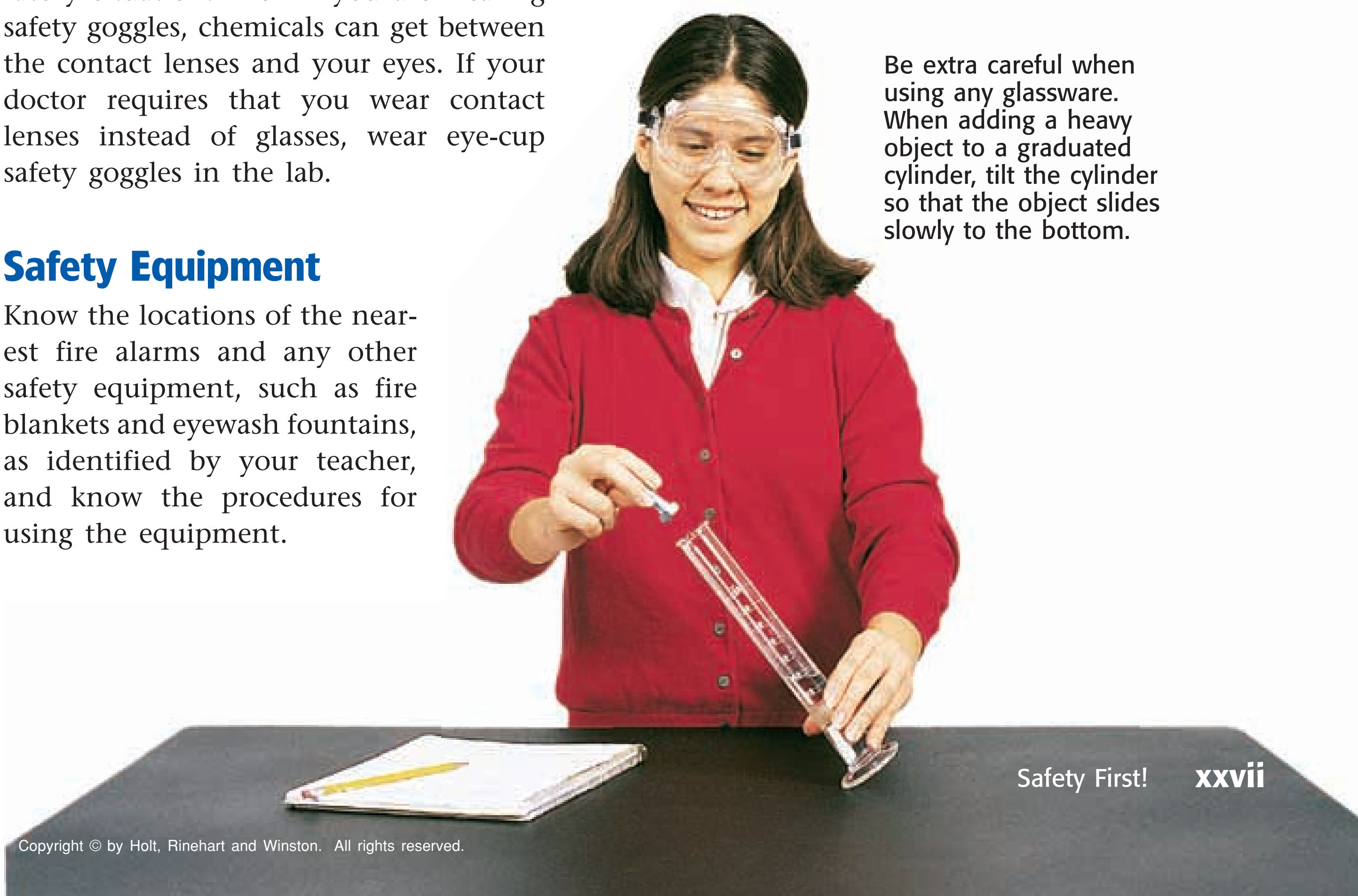
Neatness

Keep your work area free of all unnecessary books and papers. Tie back long hair, and secure loose sleeves or other loose articles of clothing, such as ties and bows. Remove dangling jewelry. Don't wear open-toed shoes or sandals in the laboratory. Never eat, drink, or apply cosmetics in a laboratory setting. Food, drink, and cosmetics can easily become contaminated with dangerous materials.

Certain hair products (such as aerosol hair spray) are flammable and should not be worn while working near an open flame. Avoid wearing hair spray or hair gel on lab days.

Sharp/Pointed Objects

Use knives and other sharp instruments with extreme care. Never cut objects while holding them in your hands. Place objects on a suitable work surface for cutting.



Be extra careful when using any glassware. When adding a heavy object to a graduated cylinder, tilt the cylinder so that the object slides slowly to the bottom.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Chemicals

Wear safety goggles when handling any potentially dangerous chemicals, acids, or bases. If a chemical is unknown, handle it as you would a dangerous chemical. Wear an apron and protective gloves when you work with acids or bases or whenever you are told to do so. If a spill gets on your skin or clothing, rinse it off immediately with water for at least 5 minutes while calling to your teacher.

Never mix chemicals unless your teacher tells you to do so. Never taste, touch, or smell chemicals unless you are specifically directed to do so. Before working with a flammable liquid or gas, check for the presence of any source of flame, spark, or heat.

Heat

Wear safety goggles when using a heating device or a flame. Whenever possible, use an electric hot plate as a heat source instead of using an open flame. When heating materials in a test tube, always angle the test tube away from yourself and others. To avoid burns, wear heat-resistant gloves whenever instructed to do so.

Electricity

Be careful with electrical cords. When using a microscope with a lamp, do not place the cord where it could trip someone. Do not let cords hang over a table edge in a way that could cause equipment to fall if the cord is accidentally pulled. Do not use equipment with damaged cords. Be sure that your hands are dry and that the electrical equipment is in the "off" position before plugging it in. Turn off and unplug electrical equipment when you are finished.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Animal Safety

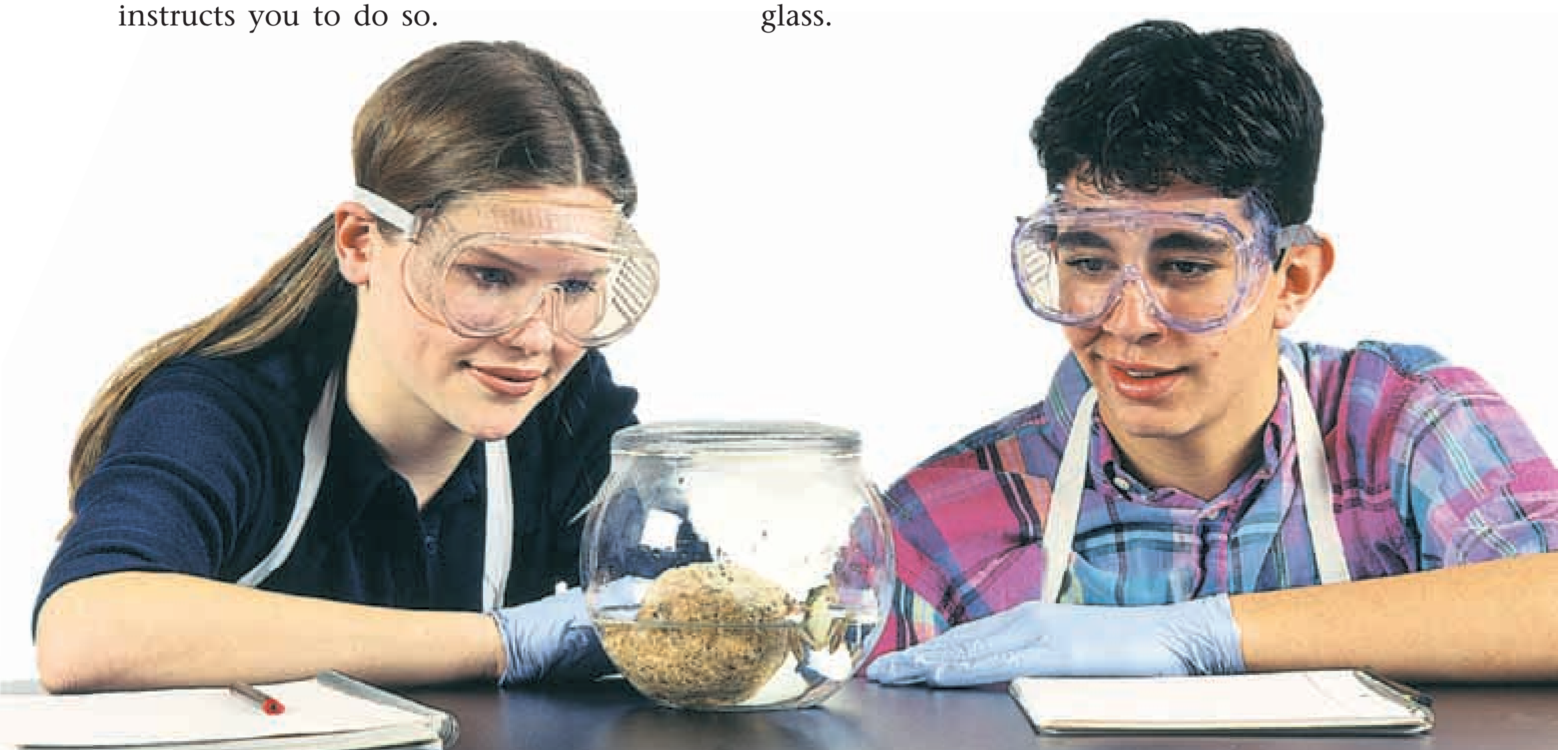
Always obtain your teacher's permission before bringing any animal into the school building. Handle animals only as your teacher directs. Always treat animals carefully and respectfully. Wash your hands thoroughly after handling any animal.

Plant Safety

Do not eat any part of a plant or plant seed used in the laboratory. Wash your hands thoroughly after handling any part of a plant. When in nature, do not pick any wild plants unless your teacher instructs you to do so.

Glassware

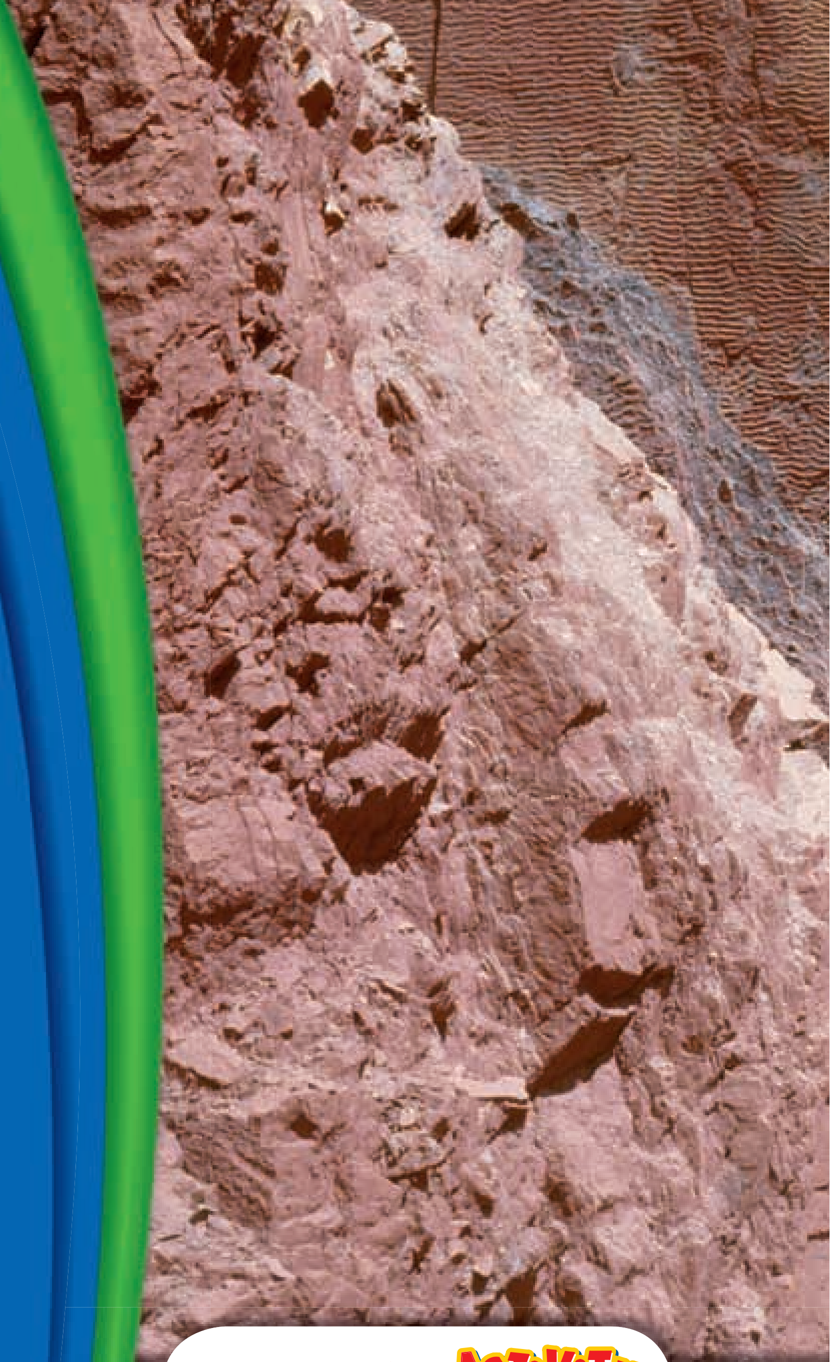
Examine all glassware before use. Be sure that glassware is clean and free of chips and cracks. Report damaged glassware to your teacher. Glass containers used for heating should be made of heat-resistant glass.



Copyright © by Holt, Rinehart and Winston. All rights reserved.

1

Science in Our World



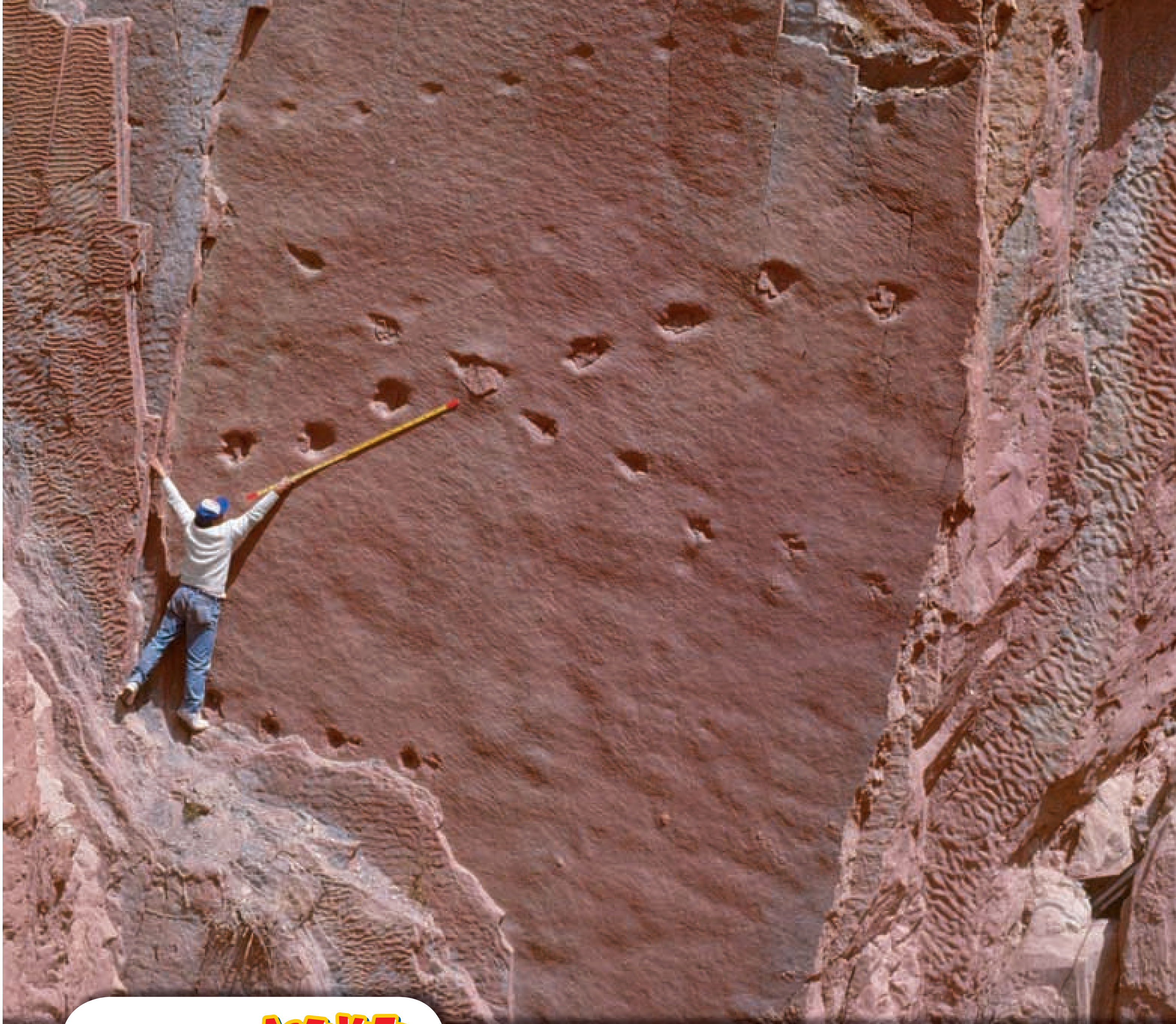
About the PHOTO

What is that man doing? Ricardo Alonso, a geologist in Argentina, is measuring the footprints left by a dinosaur millions of years ago. Taking measurements is just one way that scientists collect data to answer questions and test hypotheses.

PRE-READING ACTIVITY

FOLDNOTES **Key-Term Fold** Before you read the chapter, create the FoldNote entitled "Key-Term Fold" described in the **Study Skills** section of the Appendix. Write a key term from the chapter on each tab of the key-term fold. Under each tab, write the definition of the key term.

Copyright © by Holt, Rinehart and Winston. All rights reserved.



START-UP ACTIVITY

Mission Impossible?

In this activity, you will do some creative thinking to solve what might seem like an impossible problem.

Procedure

1. Examine an **index card.** Your mission is to fit yourself through the card. You can only tear and fold the card. You cannot use tape, glue, or anything else to hold the card together.
2. Brainstorm with a partner ways to complete your mission. Then, record your plan.
3. Test your plan. Did it work? If necessary, get **another index card** and try again. Record your new plan and the results.
4. Share your plans and results with your classmates.

Analysis

1. Why was it helpful to come up with a plan in advance?
2. How did testing your plan help you complete your mission?
3. How did sharing your ideas with your classmates help you complete your mission? What did your classmates do differently?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 1

Science and Scientists

You are on a hike in the mountains when you see something strange. You pick it up. It looks like a shell. You are curious. How could a shell be up on this mountain?

Congratulations! You just completed the first steps of being a scientist. How did you do it? You observed the world around you. Then, you asked a question about your observations. And that's part of what science is all about.

READING WARM-UP

Objectives

- Describe three ways to answer questions about science.
- Identify three benefits of science.
- Describe five jobs that use science.

Terms to Learn

science

READING STRATEGY

Reading Organizer As you read this section, create an outline of the section. Use the headings from the section in your outline.

science the knowledge obtained by observing natural events and conditions in order to discover facts and formulate laws or principles that can be verified or tested

Science Starts with a Question

Science is the knowledge gained by observing the natural world. Asking a question can help you gather knowledge. The world around you is full of amazing things that can lead you to ask questions, such as those in **Figure 1.**

Reading Check What is science? (*See the Appendix for answers to Reading Checks.*)

In Your Own Neighborhood

Take a look around your school and around your neighborhood. Most of the time, you take things that you use or see every day for granted. However, one day you might look at something in a new way. That's when a question hits you! You might sit under the tree in front of your school every day. At some point, you may wonder how the leaves change color.

The World and Beyond

Do you think that you might get tired of asking questions about things in your neighborhood? Then just remember that the world is a big place. You could ask questions about deserts, forests, or sandy beaches. Many different plants and animals live in each of these places, and the environment is full of rocks, soil, and water.

But the Earth is not the final place to look for questions. You can look outward to the moon, sun, and planets in our solar system. And beyond that, you have the rest of the universe! There seems to be enough questions to keep scientists busy for a long time.

Figure 1 *Part of science is asking questions about the world around you.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Investigation: The Search for Answers

Once you ask a question, it's time to look for an answer. But how do you start your investigation? Well, there are several methods that you can use.

Research

You can find answers to some of your questions by doing research, as shown in **Figure 2.** You can ask someone who knows a lot about the subject of your question. You can look up information in textbooks, encyclopedias, and magazines. You could also search on the Internet. You might learn more about your subject if you find the report of an experiment that someone did. But be sure to think about the source of the information that you find. Scientists use information only from reliable sources.

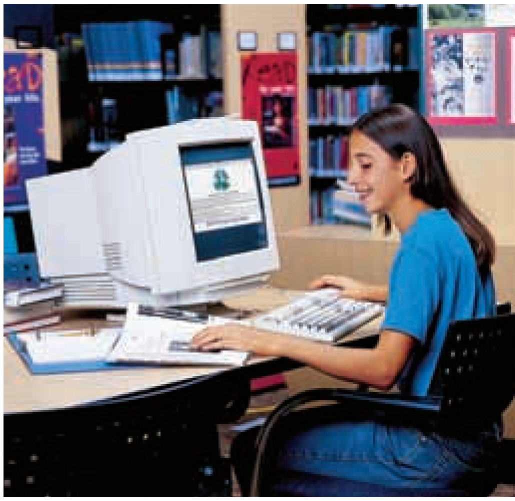


Figure 2 *A library is a good place to begin your search for answers.*

Observation

You can also find answers to questions by making careful observations. For example, if you want to know which birds live around you, you could go for a walk and look for them. Or you could hang a bird feeder outside your window and observe the birds that use it.

Experimentation

You can even answer some of your questions by doing an experiment, as shown in **Figure 3.** Your research might help you plan your experiment. And, of course, you'll need to make careful observations during the experiment. What do you do if your experiment needs materials or conditions that are hard to get? For example, what do you do if you want to see how crystals grow in space? Don't give up! Do more research to see if you can find the results from someone else's experiment!

CONNECTION TO Language Arts

Reading and Research
Think of a scientific question you'd like to research. Look for the answer to your question by reading books, newspapers, scientific journals, and articles on the Internet. Did all of your different sources provide similar information? Which of your sources were the most useful and reliable? Did any resources contradict each other? What is the answer to your scientific question?

Figure 3 *This student is doing an experiment to find out the hardness of a mineral.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SCHOOL to HOME

Parts of a System

Asking questions, making observations, and experimenting are key science skills. Practice your skills around the house! With a parent, inspect a simple machine, such as a pencil sharpener or a stapler. Take the item apart, and describe the role of each part. Think about how changing one part could change the entire machine. Then, put the parts back together.

ACTIVITY

Why Ask Why?

Although people cannot use science to answer every question, many questions can be answered by science. But do any of the answers really matter? Absolutely! Here are just a few ways that science affects our lives.

Saving Lives

Using science, people have answered the question, "How can bicycle riding be made safer?" Science has helped people develop new materials and designs for safer helmets. Effective helmets help protect a rider's head if it hits the ground. These helmets can prevent injuries that lead to brain damage or even death. Scientific research has led to many life-saving discoveries, such as medicines, weather predicting, and disease prevention.

Using Resources Wisely

Science has also helped answer the question, "How can resources be made to last longer?" For example, by recycling paper, people can save trees, as shown in **Figure 4.** Recycling helps protect forests and saves fuel and chemicals used to make paper from trees. Also, scientists have learned to plan ahead so that resources are not used up. For example, many areas where trees are cut down are also sites where new trees are planted. Scientists help determine how to help these trees remain healthy and grow quickly.

Reading Check **What are the benefits of recycling paper?**

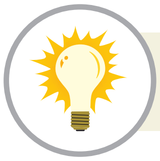
Figure 4 **Resources Saved Through Recycling**

Compared with making the paper originally, recycling 1 metric ton (1.1 tons) of paper:

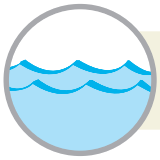
produces 30 kg (66 lb) less air pollution

uses 2.5 m^3 (3.3 yd^3) less landfill space

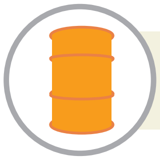
uses 18.7 fewer trees



uses 4,500 kWh less energy



uses 29,100 L (7,700 gal) less water



uses 1,800 L (470 gal) less oil

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Healthy Surroundings

Science has helped people answer the question, "How can we reduce the threat of a polluted environment?" Pollution in our surroundings can harm our health and the health of other living things. Air pollution can lead to acid precipitation (pree SIP uh TAY shuhn), which can hurt plants and damage buildings. Pollution in the oceans harms plants and animals that live there. By making less pollution, people can protect the environment and reduce the threat to their health.

One way that scientist have helped reduce pollution is by finding ways that cars can produce less exhaust. Scientists have developed lightweight materials that can be used to make lighter cars. Lighter cars are easier to move than heavier cars, so they burn less fuel. Therefore, lighter cars make less pollution. Science has also helped people develop new types of cars, such as the one in **Figure 5.**

Figure 5 *This car makes less air pollution than most cars do because it runs on batteries.*

Scientists All Around You

Scientists work in many places. If you think about it, any person who asks questions and looks for answers could be called a scientist! Keep reading to take a look at just a few people who use science in their jobs.

Environmental Scientist

To protect the environment, people need to know how and where they are damaging the world around them. An *environmental scientist* is a person who studies how humans interact with their environment. As shown in **Figure 6,** environmental scientists can find out if humans are damaging the environment. Environmental scientists are helping people save Earth's resources and use these resources more wisely.

Figure 6 *This environmental scientist is testing water quality.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 7 *The Mississippi River helped St. Louis, Missouri, become the large city that it is today. Boats were able to carry supplies and people to and from St. Louis.*

Cartographer

A *cartographer* (kahr TAHG ruh fuhr) makes maps of the surface of the Earth. These maps can be used to plan how cities can grow. Have you ever wondered why cities were built where they are? Often, a city is built in a place because of the features of the land. Many cities, such as the one in **Figure 7,** were built near rivers. Others were built near lakes or oceans. Bodies of water allow the use of boats to move people and things. Rivers and lakes also provide water for drinking and for raising crops. Maps help people keep track of these natural resources.

Figure 8 *These zoologists are working to preserve populations of endangered red wolves.*

Engineer

An *engineer* (EN juh NIR) puts scientific knowledge to practical use. Some engineers design and build the buildings, roads, and bridges that make up cities, such as the city in **Figure 7.** Others design and build electronic things, such as computers and televisions. Some even design processes and equipment to make chemicals and medicines. Engineers may work for universities, governments, and private companies.

Zoologist

A *zoologist* (zoh AHL uh jist) studies animals. The men shown in **Figure 8** are part of a study on how to protect an endangered species. Some animals are in danger of becoming extinct because of the loss of habitats where the animals live. By learning about animals' needs, zoologists hope to make a plan to help protect many species from dying out.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Science Educator

A *science educator* is a person who teaches others about science. Learning about science can help people understand how the world works. With education, people can be aware of the effects of their actions. As a result, people can act in ways that are healthy for themselves and others around them. Many science educators teach at schools. Others work at zoos, at aquariums, or in national parks, as shown in **Figure 9.**

Reading Check Where do science educators work?

Figure 9 *Some science educators work as park rangers in national parks.*

SECTION Review

Summary

- Science is the knowledge gained by observing the natural world.
- Scientists answer questions by using research, observation, and experimentation to collect data. Often, there is more than one good way to analyze and interpret data.
- Knowledge gained through science helps people protect lives, resources, and the environment.
- People use science in many types of jobs. Some people who use science in their jobs are environmental scientists, cartographers, engineers, zoologists, and science educators.

Using Key Terms

1. In your own words, write a definition for the term *science*.

Understanding Key Ideas

2. How do scientists investigate their questions?
3. What are three ways that knowledge gained through scientific discoveries can benefit the world around you?
4. Which of the following careers does NOT rely on science?
   a. environmental science
   b. cartography
   c. zoology
   d. None of the above
5. What are some resources that you can use to do research?

Math Skills

6. If recycling 1 metric ton of paper saves 4,500 kWh of energy, how much energy is saved by recycling 2.75 metric tons of paper?
7. Imagine that you are a cartographer who needs to draw a map that has the following scale: 1 cm = 1 m. How long would the line representing a wall that is 8.5 m long be?

Critical Thinking

8. **Consumer Focus** Your family usually buys the leading brand of toothpaste. A 5 oz tube of this toothpaste costs $3.00. You notice that a 5 oz tube of another brand costs $2. Which brand is cheaper? What other information would you need in order to decide which brand was a better value?
9. **Applying Concepts** Imagine that you were camping during a meteor shower. You were amazed at what you saw, and you wanted to know what causes a shooting star. Name two ways that you could investigate the cause of a shooting star.

SCILINKS® NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Recycling; Careers in Science
SciLinks code: HSM1277; HSM0225

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 2

Scientific Methods

READING WARM-UP

Objectives

- Identify the steps used in scientific methods.
- Formulate testable hypotheses.
- Explain how scientific methods are used to answer questions and solve problems.

Terms to Learn

scientific methods
observation
hypothesis
data

READING STRATEGY

Reading Organizer As you read this section, make a flowchart of the possible steps in scientific methods.

Standing by a river, several long-necked dinosaurs quietly chew on plants. Through the trees, they see an alosaurus (AL oh SAWR uhs), the most common meat-eating dinosaur of the Jurassic period.

This scene is not based on imagination alone. Even though scientists have never seen a dinosaur, they have been studying dinosaurs for years! How can that be? Scientists gather bits of information about dinosaurs and their environment from fossils. Then, they re-create what the Earth might have been like long ago. They use imagination and scientific methods.

What Are Scientific Methods?

When scientists observe the natural world, they often think of a question or problem. But scientists don't just guess at answers. **Scientific methods** are the ways in which scientists answer questions and solve problems.

As scientists look for answers, they often use the same steps. But there is more than one way to use the steps. Look at **Figure 1.** Scientists may use all of the steps or just some of the steps during an investigation. They may even repeat some of the steps or do the steps in a different order. It all depends on what works best to answer their question.

scientific methods a series of steps followed to solve problems

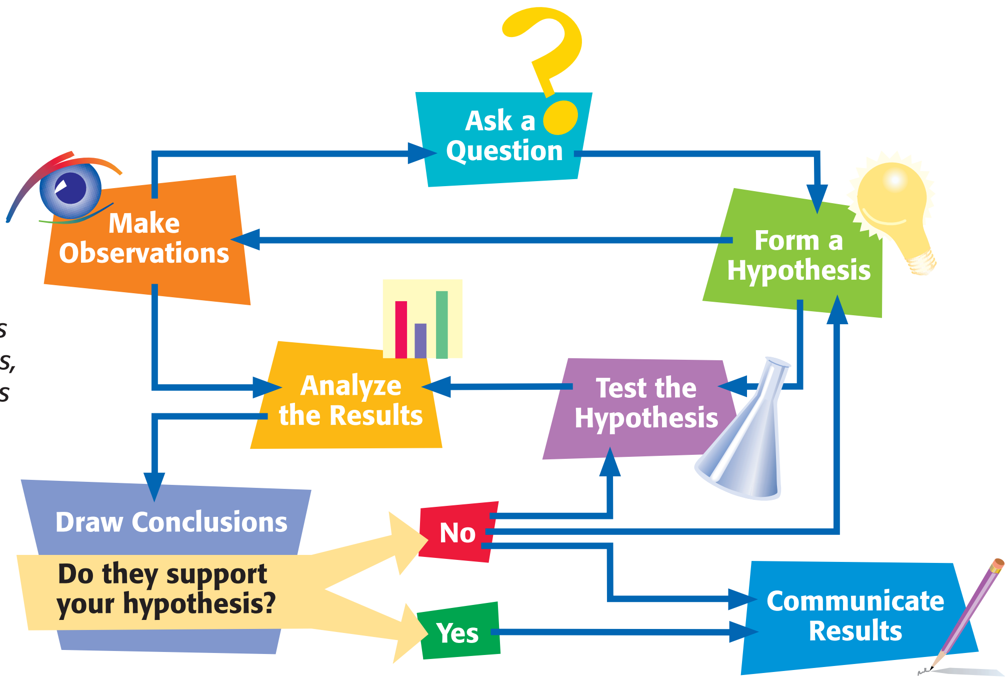


Figure 1 *Scientific methods often involve the same steps, but the steps are not always used in the same order.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Ask a Question

Asking a question helps focus the purpose of an investigation. Scientists often ask a question after making observations. An **observation** is the act of using the senses to gather information. Observations can be made at any point in an investigation.

There are many kinds of observations. Observations may describe the hardness or softness of a rock. They may describe the color of a substance. Even the patterns in behavior of an animal can be described by observations. Measurements are observations that are made with tools, such as metersticks, stopwatches, and thermometers. Observations lead to answers only when they are accurate and carefully recorded.

observation the process of obtaining information by using the senses

A Dinosaur-Sized Question

In 1979, two people on a hike found dinosaur bones in the area of northwestern New Mexico shown in **Figure 2.** Soon after, David D. Gillette, a scientist who studies fossils, went to see the bones. After observing the bones, Gillette may have asked, "What kind of dinosaur did these bones come from?" Gillette would have to use scientific methods to come up with an answer that he could trust.

Reading Check **Why do scientists use scientific methods to answer questions?** (*See the Appendix for answers to Reading Checks.*)

Figure 2 *Bones were found in this part of New Mexico.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Form a Hypothesis

hypothesis an explanation that is based on prior scientific research or observations and that can be tested

When scientists want to investigate a question, they form a hypothesis. A **hypothesis** is a possible explanation or answer to a question. It is sometimes called an educated guess. The hypothesis is a scientist's best answer to the question. But a hypothesis can't be just any answer. Someone must be able to test the hypothesis to see if it is true.

From his observations and previous knowledge about dinosaurs, Gillette formed a hypothesis about the bones. He said that the bones, seen in **Figure 3,** came from a kind of dinosaur not yet known to scientists. This hypothesis was Gillette's best testable explanation. To test it, Gillette would have to do a lot of research.

Make Predictions

Before scientists test a hypothesis, they often make predictions. To make a prediction, you say what you think will happen in your experiment or investigation. Predictions are usually stated in an if-then format. For example, Gillette could make the following prediction: If the bones are from a dinosaur not yet known to science, then at least some of the bones will not match any dinosaur bones that have been studied before. Sometimes, scientists make many predictions about one experiment. After predictions are made, scientists can do experiments to see which predictions, if any, support the hypothesis.

Figure 3 *Gillette and his team had to dig out the bones carefully before studying them.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Test the Hypothesis

A hypothesis must be tested for scientists to learn whether an idea can be supported scientifically. Scientists test hypotheses by gathering data. **Data** are any pieces of information gathered through experimentation. The data can help scientists tell if the hypotheses are valid.

To test his hypothesis, Gillette took hundreds of measurements of the bones, as shown in **Figure 4.** He compared his measurements with those of bones from known dinosaurs. He visited museums and talked with other scientists. After gathering all of these data, Gillette was ready for the next step toward answering his question.

data any pieces of information acquired through observation or experimentation

Figure 4 *To test his hypothesis, Gillette took hundreds of measurements of the bones.*

Under Control

To test a hypothesis, a scientist may conduct a controlled experiment. A *controlled experiment* tests only one factor at a time. The one factor that is changed in a controlled experiment is called a *variable*. By changing only the variable, scientists can see the results of just that one change.

Not all investigations are made by doing controlled experiments. Sometimes, it is not possible to use a controlled experiment to test something. Also, some scientists depend on observations more than they depend on experiments to test their hypotheses. By observing nature, scientists can often collect large amounts of data about their hypotheses. When large amounts of data support a hypothesis, the hypothesis is probably valid.

Reading Check **What is a variable?**

CONNECTION TO Geology

Laguna Colorada In some parts of the world, lake water doesn't look blue. In parts of Bolivia, the lakes may be green, yellow, or red! One Bolivian lake, Laguna Colorada, is a deep-red body of water surrounded by a white stretch of flat land. The land around the lake is white because of all of the salty minerals in the rock there. Some of the lakes are colored by minerals. Others are colored by the microorganisms that live there. How could you find out why Laguna Colorada is red?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Analyze the Results

After they finish their tests, scientists must analyze the results. Analyzing the results helps scientists construct reasonable explanations based on the evidence that has been collected. Scientists often make tables and graphs to arrange their data. **Figure 5** shows how Gillette organized his data. When Gillette analyzed his results, he found that the bones of the mystery dinosaur did not match the bones of any known dinosaur. The bones were either too large or too different in shape.

Reading Check **What are two ways that scientists can organize their data?**

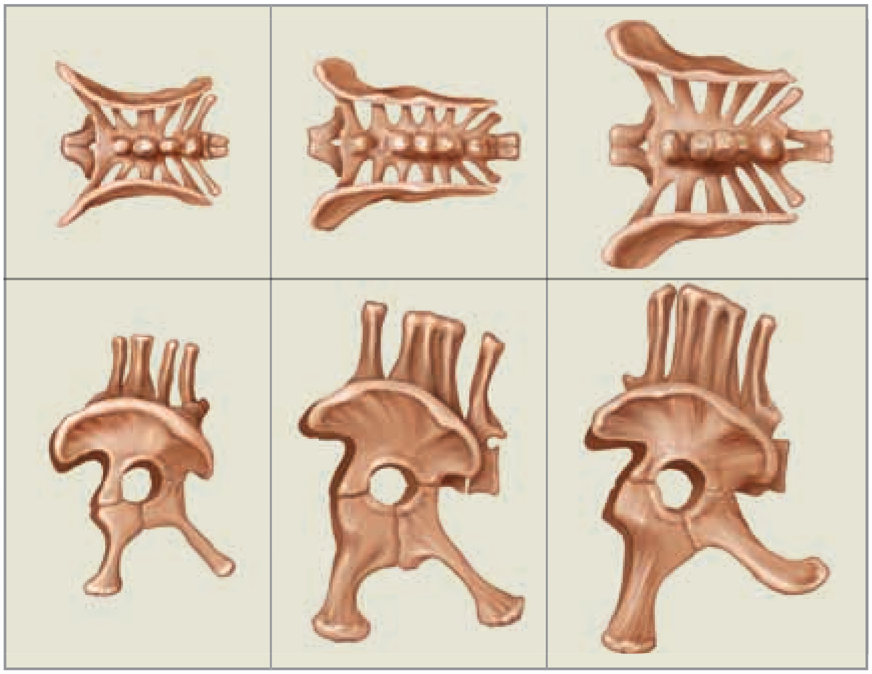


Figure 5 *By organizing his measurements in a chart, Gillette could analyze his results more easily.*

Figure 6 *This model of the skeleton of* Seismosaurus hallorum *is based on Gillette's research. The bones shown in the darker color are the bones that have been found so far.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Quick Lab

Mapping a Sphere

1. Examine a **soccer ball,** and notice the patterns on the ball.
2. Place different **stickers** on each pentagon of the ball.
3. Now, try mapping the images from the soccer ball onto a **flat piece of paper.**
4. What problems came up when you tried to represent a sphere on a flat piece of paper?
5. Use your experience to draw a conclusion about why maps of the entire Earth are often represented on a globe. Then, explain why flat maps of the entire Earth are often distorted.

Draw Conclusions

After analyzing the results of their tests, scientists must conclude if the results support the hypothesis. Proving that a hypothesis is not true can be as valuable as proving that it is true. If the hypothesis is not supported, scientists may repeat the investigation to check for mistakes. Or, scientists may look at the original question in a new way, ask new questions, and form new hypotheses. New questions and hypotheses can lead to new investigations and discoveries.

From all of his work, Gillette concluded that the bones found in New Mexico, shown in the model in **Figure 6,** were indeed from a yet unknown dinosaur. The dinosaur was about 45 m (148 ft) long and had a mass of almost 100 metric tons. The creature certainly fit the name that Gillette gave it—*Seismosaurus hallorum,* the "earth shaker."

Internet Activity

For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HZ5WESW.**

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Communicate Results

After finishing an investigation, scientists communicate their results. By doing so, scientists share what they have learned. Scientists communicate by writing reports for scientific journals and by giving talks. They can also put their results on the Internet. In fact, scientists use computers to prepare research reports as well as to share data with other scientists.

Science depends on sharing information. Sharing allows other scientists to repeat experiments to see if they get the same results. Also, by sharing, scientists can compare hypotheses and form consistent explanations. Sometimes, new data lead scientists to change their hypotheses.

Gillette shared his discovery of *Seismosaurus hallorum* at a press conference at the New Mexico Museum of Natural History and Science. He later sent a report that described his investigation to the *Journal of Vertebrate Paleontology.*

CONNECTION TO Physics

Defining Technology As technologies are developed, scientists are able to investigate questions in new ways. How would you define the word *technology*? Consider the pros and cons of the following definitions: 1) artifact or hardware; 2) methodology or technique; 3) system of production; or 4) social-technical system. Can you find evidence to support the use of any of these definitions? Give an example of a technology that fits each definition.

Reading Check **Name three ways that scientists share results.**

Case Closed?

All of the bones that Gillette found have been dug up from the ground. But as **Figure 7** shows, the fun is not over yet! The work on *Seismosaurus hallorum* continues. The remains of one of the largest dinosaurs ever discovered are still being studied. Like so many other investigations, Gillette's work led to new questions to be answered.

Figure 7 *David Gillette continues to study the bones of* Seismosaurus hallorum *for new views into the past.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION Review

Summary

- Scientific methods are the ways in which scientists follow steps to answer questions and solve problems.
- Any information gathered through the senses is an observation. Observations often lead to the formation of questions and hypotheses.
- A hypothesis is a possible explanation or answer to a question. A well-formed hypothesis can be tested by experiments.
- A controlled experiment tests only one factor at a time in order to determine the effects of changes to just that one factor.
- After testing a hypothesis, scientists analyze the results and draw conclusions about whether the hypothesis is supported.
- Communicating results allows others to check the results, add to their knowledge, form new hypotheses, and design new experiments.

Using Key Terms

1. Use the following terms in the same sentence: *scientific methods, observations, hypothesis,* and *data.*

Understanding Key Ideas

2. Which of the following statements about the steps of scientific methods is true?
   a. Steps must always be used in the same order.
   b. All steps must be used.
   c. Steps are repeated sometimes.
   d. The steps must support the hypothesis.
3. The following statements could have been made during Gillette's field investigation. Which statement is a testable hypothesis?
   a. Dinosaur bones were found in New Mexico.
   b. The bones are from a known dinosaur.
   c. One of the ribs is 2 m long.
   d. The first step in studying the bones is to dig them out of the ground.
4. What is an observation? Write down one observation about the room that you are in at this moment.
5. What is a controlled experiment?

Critical Thinking

6. **Analyzing Processes** How could two scientists working to answer the same question draw different conclusions?
7. **Applying Concepts** What are two ways that you could analyze data about temperature changes over many years? What are the benefits and limitations of each method?

Interpreting Graphics

8. The table below shows how long one bacterium takes to divide into two bacteria. Plot the data on a graph. Put temperature on the x-axis and the time to double on the y-axis. Do not graph values for which there is no growth. What temperature allows the bacteria to grow the fastest?

Temperature (°C)	Time to double (min)
10	130
20	60
25	40
30	29
37	17
40	19
45	32
50	no growth

SCILINKS®
NSTA
Developed and maintained by the National Science Teachers Association
For a variety of links related to this chapter, go to www.scilinks.org
Topic: Scientific Methods
SciLinks code: HSM1359

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 3

Scientific Models

Imagine you are studying volcanoes. How do you think baking soda, vinegar, and some clay could help you?

READING WARM-UP

Objectives

- Use models to represent the natural world.
- Identify the limitations of models.
- Describe theories and laws.

Terms to Learn

model
theory
law

READING STRATEGY

Paired Summarizing Read this section silently. In pairs, take turns summarizing the material. Stop to discuss ideas that seem confusing.

You might not think these things alone could help you. But you could use them to build a model of a volcano. Then they might help you understand volcanoes a little better.

Types of Scientific Models

A **model** is a representation of an object or system. Models often use familiar objects or ideas that stand for other things. That's how a model can be a tool for understanding the natural world. A model uses something familiar to help you understand something that is not familiar. Models can be used to explain the past and the present. They can even be used to predict future events. However, keep in mind that models have limitations. Three major kinds of scientific models are physical, mathematical, and conceptual models.

model a pattern, plan, representation, or description designed to show the structure or workings of an object, system, or concept

Physical Models

Model airplanes, maps, and dolls are physical models. Some physical models, such as a doll, look like the thing they model. However, a limitation of a doll as the model of a baby is that the doll doesn't act like a baby. Other models, such as the one shown in **Figure 1,** look and act at least somewhat like the real thing.

Figure 1 *The model volcano looks a little bit like the real volcano, but it has its limitations. The model lava is not formed in the same way or at the same temperature as the real lava.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

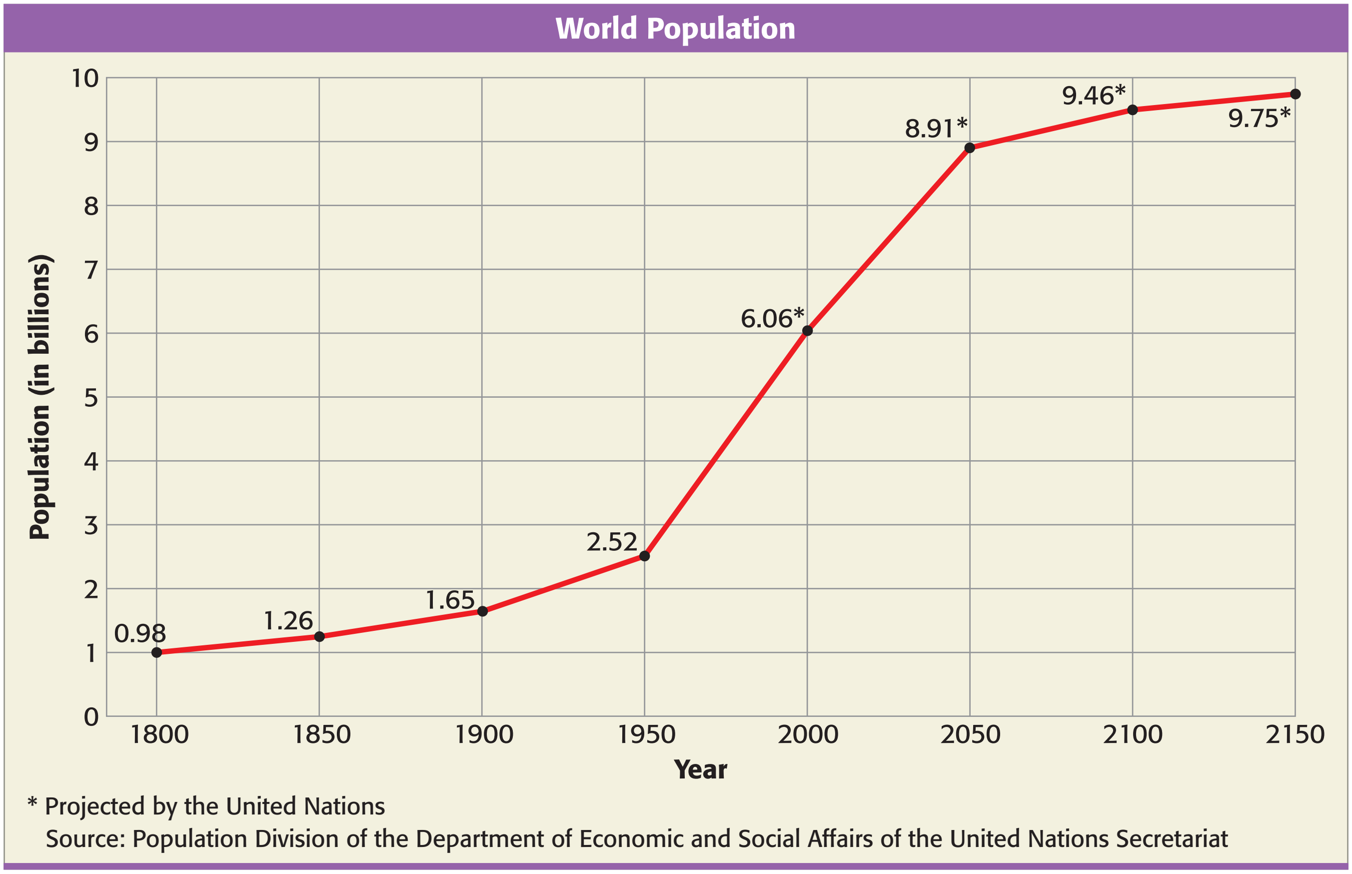


Figure 2 *This graph shows human population growth predicted by a mathematical model run on a computer.*

Mathematical Models

A mathematical model is made up of mathematical equations and data. Simple mathematical models allow you to calculate things such as how far a car will go in an hour. Other models are so complex that only computers can handle them. Look at **Figure 2.** Scientists use a mathematical model to help predict how fast the number of people on Earth will grow and how many resources people will use. Some of these very complex models have many variables. Using the most correct data does not make the prediction correct. A change in a variable that was not predicted could cause the model to fail.

Conceptual Models

The third kind of model is a conceptual model. Some conceptual models are systems of ideas. Others are based on making comparisons with familiar things to help illustrate or explain an idea. One example of a conceptual model is the system that scientists use to classify living things. By using a system of ideas, scientists can group living things by what they have in common. This type of model allows scientists to better understand each group of living things.

Reading Check **What are three kinds of models?** (*See the Appendix for answers to Reading Checks.*)

CONNECTION TO Language Arts

Analogies Many writers use analogies. An analogy points to similarities between two things that are otherwise unlike each other. Do you think scientists use analogies? What could be some strengths and weaknesses of using analogies to describe events and objects in scientific explorations?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Just the Right Size

Models are often used to represent things that are very small or very large. Particles of matter are too small to see. The Earth or the solar system is too large to see completely. In these cases, a model can help you picture the thing in your mind. Models can even help you observe features that are not easily observed in real life. With a model, you can examine each of the layers inside the Earth.

Reading Check **How can people picture in their minds objects that are too small or too large to see completely?**

Building Scientific Knowledge

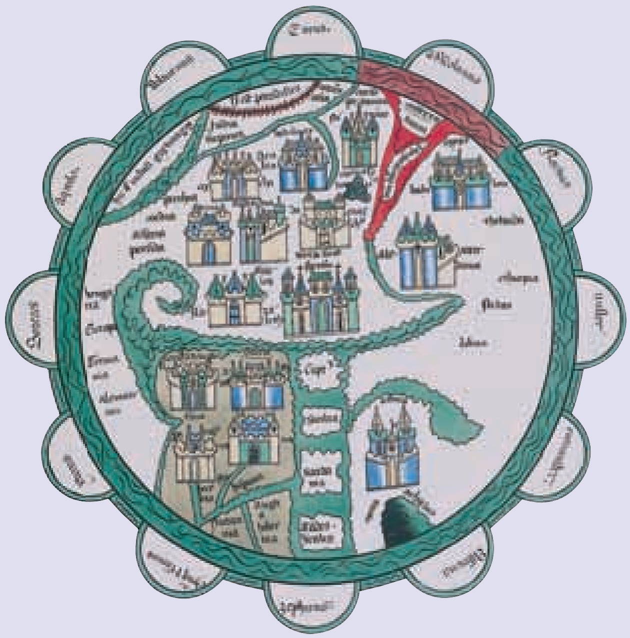
theory an explanation that ties together many hypotheses and observations

law a summary of many experimental results and observations; a law tells how things work

Models are often used to help illustrate and explain scientific theories. In science, a **theory** is a unifying explanation for a range of hypotheses and observations that have been supported by testing. A theory not only can explain an observation you've made but also can predict what might happen in the future.

Scientists use models to help guide their search for new information. This information can help support a theory or show it to be wrong. Keep in mind that models can be changed or replaced. These changes happen because new observations cause scientists to change their theories. You can compare an old model with a current one in **Figure 3.**

Figure 3 *Scientists' model of Earth changed as new information was gathered.*



Model of Earth: 1000 CE

Model of Earth: Current

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Scientific Laws

What happens when a theory and its models correctly predict the results of many different experiments? A scientific law could be formed. In science, a **law** is a summary of many experimental results and observations. A law tells you how things work.

A law tells you to expect the same thing to happen every time. Look at **Figure 4.** Every object in the universe is attracted to every other object. This fact is summed up by the *law of universal gravitation*. This law says that you can always expect two objects to be attracted to one another. It also helps you calculate the size of the attraction. The size of the attraction depends on the masses of the objects and the distance between them. However, the law does not explain why there is an attraction.

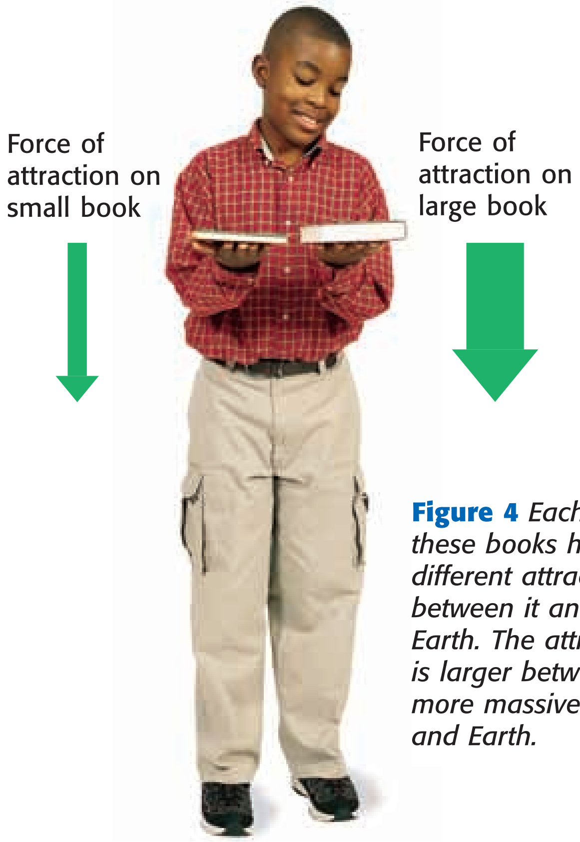


Figure 4 *Each of these books has a different attraction between it and Earth. The attraction is larger between the more massive book and Earth.*

SECTION Review

Summary

- Three main types of models are physical, mathematical, and conceptual.
- A model is a representation of an object or system. Models often use familiar things to represent unfamiliar things that may be difficult to observe.
- Scientific knowledge is built as scientists form laws and revise scientific hypotheses, models, and theories.

Using Key Terms

In each of the following sentences, replace the incorrect term with the correct term from the word bank.

theory model law

1. A conclusion is an explanation that matches many hypotheses but may still change.
2. A hypothesis tells you exactly what to expect in a situation.
3. A variable represents an object or a system.

Understanding Key Ideas

4. What are the three main types of models?
5. How do scientists form theories and laws?

Math Skills

6. If Jerry is 2.1 m tall, how tall is a scale model of Jerry that is 10% of his size?

Critical Thinking

7. **Applying Concepts** Draw a map showing the way from your school to your home. What type of model have you made? Identify any symbols that you used to represent things on your map. What are some limitations of your model?
8. **Forming Hypotheses** How could you use a solar system model to hypothesize why the moon appears to change shape?

SCILINKS® NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Using Models
SciLinks code: HSM1588

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 4

Tools, Measurement, and Safety

READING WARM-UP

Objectives

- Describe three kinds of tools.
- Explain the importance of the International System of Units.
- Describe how to measure length, area, mass, volume, and temperature.
- Identify lab safety symbols, and demonstrate safe practices during lab investigations.

Terms to Learn

meter	volume
area	temperature
mass	

READING STRATEGY

Reading Organizer As you read this section, make a concept map by using the terms above.

Would you use a hammer to tighten a bolt on a bicycle? You probably wouldn't. To be successful in many tasks, you need the correct tools.

Tools for Science

Scientists use many tools. A *tool* is anything that helps you do a task. If you observe a jar of pond water, you may see a few creatures swimming around. But a microscope can help you see many creatures that you couldn't see before. And a graduated cylinder can help you measure the water in the jar. Different tools help scientists gather specific kinds of data.

Tools for Seeing

Microscopes help you make careful observations of things that are too small to see with just your eyes. The compound light microscope in **Figure 1** is made up of three main parts—a tube that has lenses at each end, a stage, and a light. When you place what you want to see on the stage, light passes through it. The lenses magnify the image.

Reading Check **Name the three main parts of a compound light microscope.** (*See the Appendix for answers to Reading Checks.*)

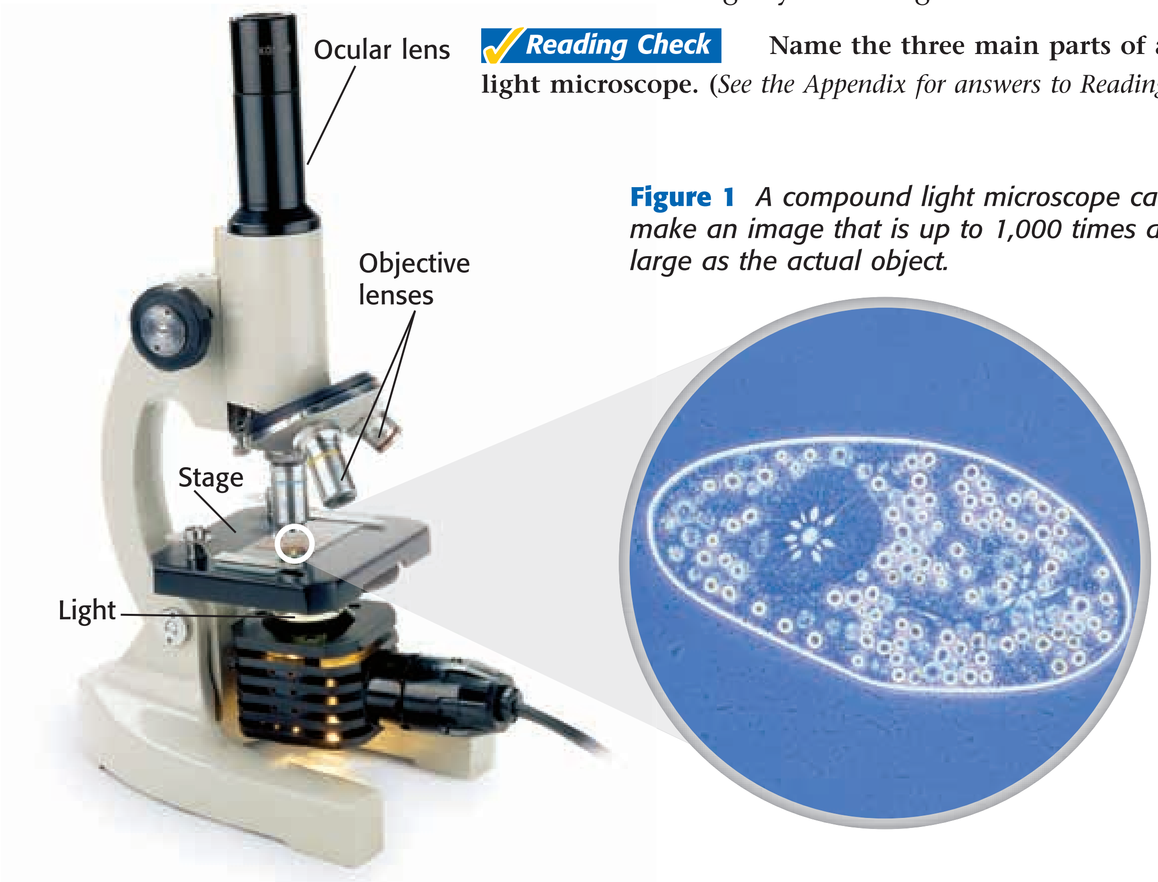


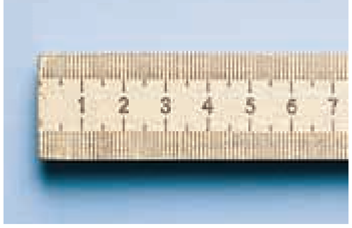
Figure 1 *A compound light microscope can make an image that is up to 1,000 times as large as the actual object.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 2 **Measurement Tools**

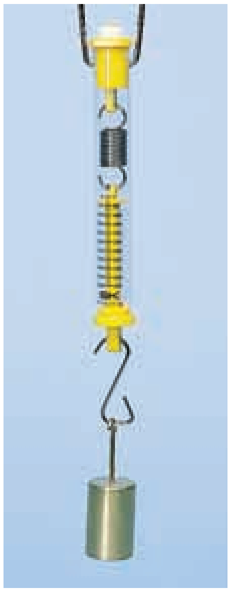
You can use a **graduated cylinder** to measure volume.

You can use a **stopwatch** to measure time.

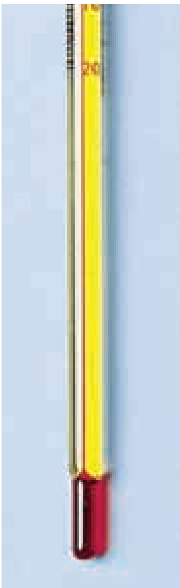


You can use a **meterstick** to measure length.

You can use a **spring scale** to measure force.



You can use a **balance** to measure mass.



You can use a **thermometer** to measure temperature.

Tools for Measuring

You might remember that one way to collect data during an experiment is to take measurements. To have the best measurements possible, you need to use the proper tools. Stopwatches, metersticks, and balances are some of the tools you can use to make measurements. Thermometers, spring scales, and graduated cylinders are also helpful tools. **Figure 2** explains what characteristics these tools can be used to measure.

Tools for Analyzing

After you collect data, you need to analyze them. Perhaps you need to find the average of your data. Calculators are handy tools that help you do calculations quickly. Or you might show your data in a graph or a figure. A computer that has the correct software can help you make neat, colorful figures. In fact, computers have become invaluable tools for collecting, storing, and analyzing data. Of course, even a pencil and graph paper are tools that you can use to graph your data.

Quick Lab

See for Yourself

1. Use a **metric ruler** to measure the length and width of one of your fingernails. Draw and describe the details of your fingernail.
2. Look at the same fingernail through a **magnifying lens.** Now, draw the details of your fingernail as seen with magnification.
3. How does using a magnifying lens change what details you can see?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Measurement

Hundreds of years ago, different countries used different systems of measurement. At one time in England, the standard for an inch was three grains of barley placed end to end. Other modern standardized units were originally based on parts of the body, such as the foot. Such systems were not very reliable. Their units were based on objects that had different sizes.

The International System of Units

In time, people realized that they needed a simple and reliable measurement system. In the late 1700s, the French Academy of Sciences set out to make that system. Over the next 200 years, the metric system was formed. This system is now called the *International System of Units* (SI).

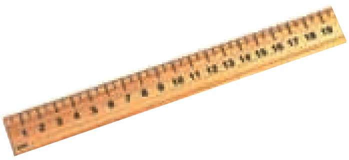
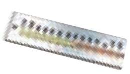
Today, most scientists and almost all countries use the International System of Units. One advantage of using the SI measurements is that they help all scientists share and compare their observations and results. Another advantage of the SI is that all units are based on the number 10. This feature makes changing from one unit to another easy. **Table 1** shows SI units for length, volume, mass, and temperature.

MATH PRACTICE ACTIVITY

Units of Measurement

Measure the width of your desk, but do not use a ruler. Pick an object to use as your unit of measurement. It could be a pencil, your hand, or anything else. Find how many units wide your desk is. Compare your measurement with those of your classmates. In your **science journal,** explain why using standard units of measurement is important.

Table 1 **Common SI Units and Conversions**

Length 	**meter (m)** kilometer (km) decimeter (dm) centimeter (cm) millimeter (mm) micrometer (µm) nanometer (nm)	1 km = 1,000 m 1 dm = 0.1 m 1 cm = 0.01 m 1 mm = 0.001 m 1 µm = 0.000001 m 1 nm = 0.000000001 m
Volume 	**cubic meter (m^3)** cubic centimeter (cm^3) liter (L) milliliter (mL)	1 cm^3 = 0.000001 m^3 1 L = 1 dm^3 = 0.001 m^3 1 mL = 0.001 L = 1 cm^3
Mass 	**kilogram (kg)** gram (g) milligram (mg)	1 g = 0.001 kg 1 mg = 0.000001 kg
Temperature 	**Kelvin (K)** Celsius (°C)	0°C = 273 K 100°C = 373 K

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Length

How long is your arm? The student in **Figure 3** could describe the length of her arm by using the **meter** (m), the basic SI unit of length. Remember that SI units are based on the number 10. If you divide 1 m into 100 parts, each part equals 1 cm. In other words, 1 cm is one-hundredth of a meter. To describe the length of microscopic objects, micrometers (µm) or nanometers (nm) are used. To describe the length of larger objects, kilometers (km) are used.

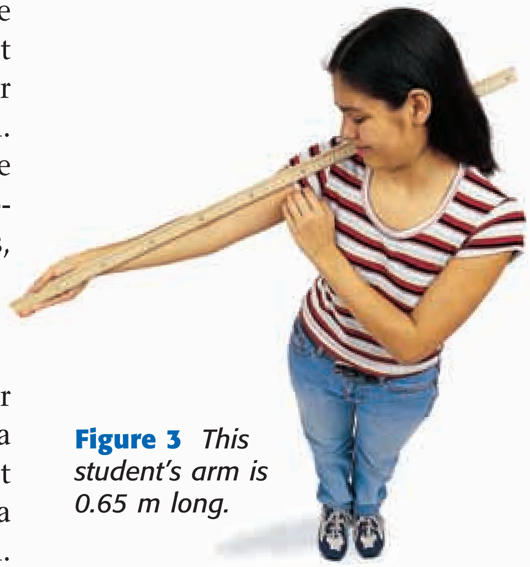


Figure 3 *This student's arm is 0.65 m long.*

Area

How much carpet would it take to cover the floor of your classroom? To answer this question, you must find the area of the floor. **Area** is a measure of how much surface an object has. Area is based on two measurements. To calculate the area of a square or rectangle, first measure the length and width. Then, use the following equation:

$$area = length \times width$$

The units for area are square units, such as square meters (m^2), square centimeters (cm^2), and square kilometers (km^2).

Reading Check **What does area measure?**

Mass

How many sacks of grain can a mule carry? The answer depends on the strength of the mule and the mass of the sacks of grain. **Mass** is the amount of matter that makes up an object. Scientists often use a balance to measure mass, as shown in **Figure 4.** The kilogram (kg) is the basic unit for mass. The kilogram is used to describe the mass of things such as sacks of grain. Many common objects are not so large, however. The mass of smaller objects, such as an apple, can be described by using grams. One thousand grams equals 1 kg. The mass of large objects, such as an elephant, is given in metric tons. A metric ton equals 1,000 kg.

meter the basic unit of length in the SI (symbol, m)

area a measure of the size of a surface or a region

mass a measure of the amount of matter in an object

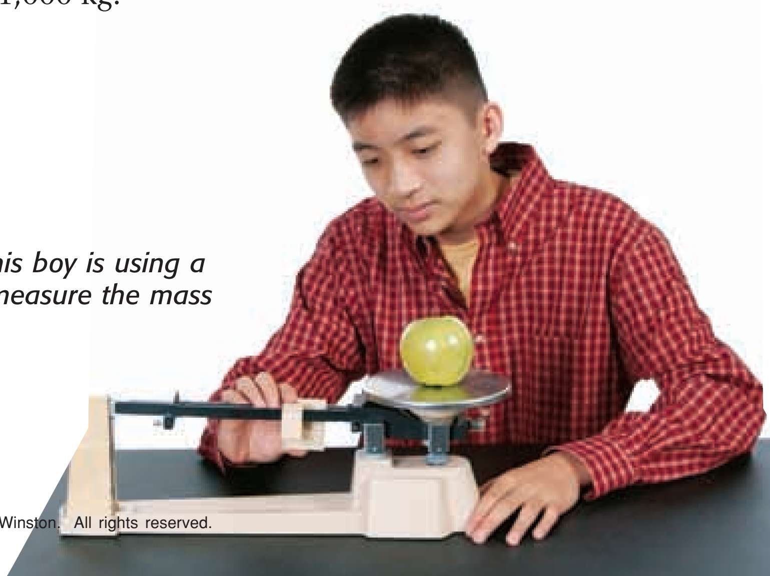


Figure 4 *This boy is using a balance to measure the mass of an apple.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

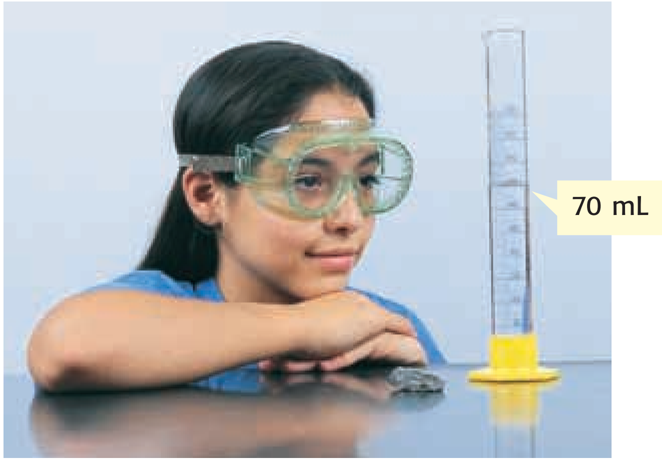
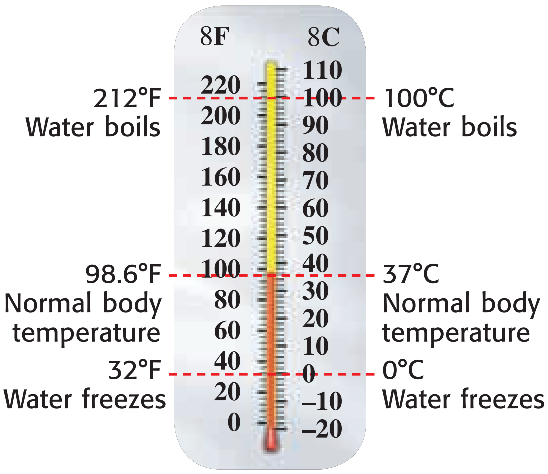


Figure 5 *Adding the rock changes the water level from 70 mL to 80 mL. So, the rock displaces 10 mL of water. Because 1 mL = 1 cm^3, the volume of the rock is 10 cm^3.*

volume a measure of the size of a body or region in three-dimensional space

temperature a measure of how hot (or cold) something is

Figure 6 *This thermometer shows the relationship between degrees Fahrenheit and degrees Celsius.*



Volume

Suppose that some hippos born in a zoo are being moved to Africa. How many hippos will fit into a cage? The answer depends on volume. **Volume** is the amount of space that something occupies or, as in the case of the cage, the amount of space that something contains.

The volume of a liquid is often given in liters (L). Liters are based on the meter. A cubic meter (1 m^3) is equal to 1,000 L. So, 1,000 L will fit into a box measuring 1 m on each side. A milliliter (mL) will fit into a box measuring 1 cm on each side. So, 1 mL = 1 cm^3. Graduated cylinders are used to measure liquid volume in milliliters.

The volume of a large, solid object is given in cubic meters (m^3). The volumes of smaller objects can be given in cubic centimeters (cm^3) or cubic millimeters (mm^3). To calculate the volume of a box-shaped object, multiply the object's length by its width and then by its height. To find the volume of an irregularly shaped object, measure the volume of liquid that the object displaces. This process is shown in **Figure 5.**

Temperature

How hot is a lava flow? To answer this question, scientists need to measure temperature. **Temperature** is a measure of how hot (or cold) something is. You probably use degrees Fahrenheit (°F) to describe temperature. Scientists often use degrees Celsius (°C). However, the kelvin (K), the SI base unit for temperature, is also used. The thermometer in **Figure 6** shows how two of these units are related.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Safety Rules!

Science can be exciting, fun, and safe if you follow your teacher's instructions. You should get your teacher's permission before starting any science investigation. Read lab procedures carefully, and pay special attention to safety information. **Figure 7** shows the safety symbols used in this book. Be sure you know these symbols and their meanings. You should also read the safety information at the beginning of this book. If you still have safety-related questions, ask your teacher for help.

Reading Check **What should you do if you don't understand what a safety symbol means?**

Figure 7 **Safety Symbols**

SECTION Review

Summary

- Scientists use tools that help them see, measure and analyze. Microscopes, metersticks, and computers are a few tools that scientists use in their investigations.
- Scientists use the International System of Units so that they can share and compare their observations and results.
- Scientists have determined standard ways to measure length, area, mass, volume, and temperature.
- Students and anyone doing science investigations should follow safety instructions and should be able to understand safety icons.

Using Key Terms

Complete each of the following sentences by choosing the correct term from the word bank.

area	mass
volume	temperature

1. The measure of the surface of an object is called ____.

2. Scientists use kilograms when measuring an object's ____.

3. The ____ of a liquid is usually described in liters.

Understanding Key Ideas

4. SI units are

a. always based on standardized measurements of body parts.

b. almost always based on the number 10.

c. used to measure only length.

d. used only in France.

5. What are three units that are used to measure temperature?

6. If you were going to measure the mass of a fly, which SI unit would be most appropriate?

7. Describe three kinds of tools, and give an example of each kind of tool.

Math Skills

8. What is the area of a garden that is 12 m long and 8 m wide?

9. What is the volume of a box if the sides of the box are each 1 m in length?

Critical Thinking

10. Predicting Consequences Give an example of what could happen if you do not follow safety rules about animal safety.

11. Applying Concepts During an experiment, you must mix chemicals in a glass beaker. What should you wear to protect yourself during this experiment?

SCILINKS® NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Tools of Science; SI Units
SciLinks code: HSM1535; HSM1390

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Using Scientific Methods

Model-Making Lab

Using Scientific Methods

Geologists often use a technique called core sampling to learn what underground rock layers look like. This technique involves drilling several holes in the ground in different places and taking samples of the underground rock or soil. Geologists then compare the samples from each hole at each depth to construct a diagram that shows the bigger picture.

In this activity, you will model the process geologists use to diagram underground rock layers. You will first use modeling clay to form a rock-layer model. You will then exchange models with a classmate, take core samples, and draw a diagram of your classmate's rock layers.

- Form a plan for your rock layers. Make a sketch of the layers. Your sketch should include the colors of clay in several layers of varying thicknesses. Note: Do not let the classmates who will be using your model see your plan.
- In the pan or box, mold the clay into the shape of the lowest layer in your sketch.
- Repeat the procedure described in the second bullet for each additional layer of clay. Exchange your rock-layer model with a classmate.

OBJECTIVES

Design a model to demonstrate core sampling.

Create a diagram of a classmate's model by using the core sample method.

MATERIALS

- knife, plastic
- modeling clay, three or four colors
- pan or box, opaque
- pencil, unsharpened
- pencils or markers, three or four colors
- PVC pipe, 1/2 in.

SAFETY

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Ask a Question

1. Can unseen features be revealed by sampling parts of the whole?

Form a Hypothesis

2. Form a hypothesis about whether taking core samples from several locations will give a good indication of the entire hidden feature.

Test the Hypothesis

3. Choose three places on the surface of the clay to drill holes. The holes should be far apart and in a straight line. (Do not remove the clay from the pan or box.)
4. Slowly push the PVC pipe through all the layers of clay. Slowly remove the pipe.
5. Gently push the clay out of the pipe with an unsharpened pencil. This clay is a core sample.
6. Draw the core sample, and record your observations. Be sure to use a different color of pencil or marker for each layer.
7. Repeat steps 4–6 for the next two core samples. Make sure your drawings are side by side and in the same order as the samples in the model.

Analyze the Results

1. **Examining Data** Look at the pattern of rock layers in each of your core samples. Think about how the rock layers between the core samples might look. Then, make a diagram of the rock layers.
2. **Organizing Data** Complete your diagram by coloring the rest of each rock layer.

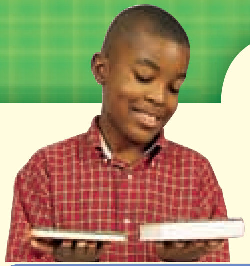
Draw Conclusions

3. **Evaluating Models** Use the plastic knife to cut the clay model along a line connecting the three holes. Remove one side of the model so that you can see the layers. How well does your rock-layer diagram match the model? Explain your answer.
4. **Evaluating Methods** What are some limitations of your diagram as a model of the rock layers?
5. **Drawing Conclusions** Do your conclusions support your hypothesis? Explain your answer.

Applying Your Data

List two ways that the core-sampling method could be improved.

Copyright © by Holt, Rinehart and Winston. All rights reserved.



Chapter Review

USING KEY TERMS

Complete each of the following sentences by choosing the correct term from the word bank.

models	science
scientific methods	hypothesis

1. The process of gathering knowledge about the natural world is called ___.

2. An explanation that is based on prior scientific research or observations and that can be tested is called a ___.

3. ___ are a series of steps followed to solve problems.

UNDERSTANDING KEY IDEAS

Multiple Choice

4. A good way to investigate answers to scientific questions is to
   - **a.** do research only.
   - **b.** make observations only.
   - **c.** do experiments only.
   - **d.** do research, make observations, and do experiments.

5. A pencil measures 14 cm long. How many millimeters long is it?
   - **a.** 1.4 mm
   - **b.** 140 mm
   - **c.** 1,400 mm
   - **d.** 1,400,000 mm

6. Which of the following units is NOT an SI unit?
   - **a.** meter
   - **b.** foot
   - **c.** liter
   - **d.** degree Celsius

7. Which of the following statements describes a limitation of models?
   - **a.** Models are large enough to be seen.
   - **b.** Models do not act exactly like the things that they model.
   - **c.** Models are smaller than the thing that they model.
   - **d.** Models use familiar things to model unfamiliar things.

8. What kind of model is a map?
   - **a.** physical model
   - **b.** conceptual model
   - **c.** mathematical model
   - **d.** hypothesis model

Short Answer

9. How could a hypothesis that is proven to be false lead to new scientific investigations?

10. How and why do scientists use models?

11. What are three types of models? Give an example of each type.

12. What problems could occur if scientists did not communicate the results of their investigations?

13. What problems could occur if the International System of Units were not used?

14. Which safety symbols would you expect to see for an experiment that requires the use of acid?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

CRITICAL THINKING

15 **Concept Mapping** Use the following terms to create a concept map: *science, scientific methods, hypothesis, problems, questions, experiments,* and *observations*.

16 **Analyzing Processes** What are the steps of scientific methods? Why don't you need to complete the steps of scientific methods in a specific order?

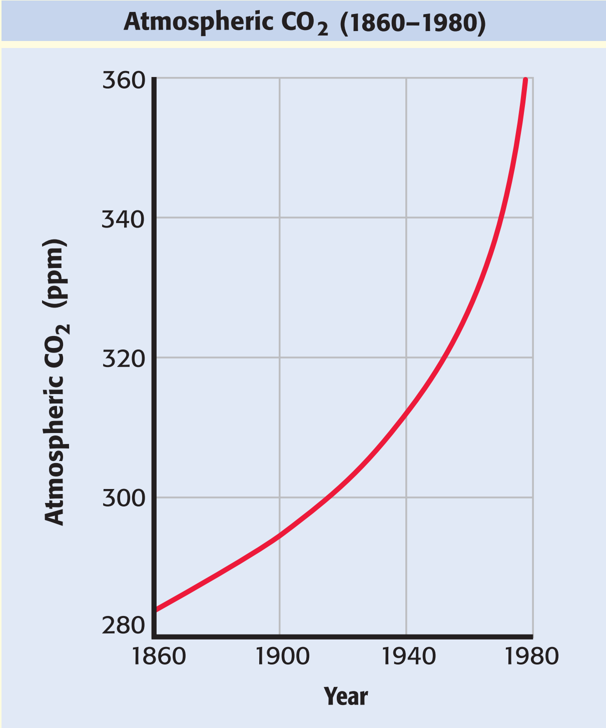
17 **Evaluating Conclusions** How could a scientist respond to another scientist who questioned her conclusion?

18 **Identifying Relationships** Science helps us save lives, use resources wisely, and have healthy surroundings. How can healthy surroundings help save lives?

19 **Making Comparisons** Why might a person who wanted to protect the environment have trouble deciding between being a science educator or an environmental scientist?

INTERPRETING GRAPHICS

Use the graph below to answer the questions that follow.



20 Has the amount of CO_2 in the atmosphere increased or decreased since 1860?

21 The line on the graph is curved. What does this curve indicate?

22 Was the rate of change in the level of CO_2 between 1940 and 1960 higher or lower than it was between 1880 and 1900? How can you tell?

23 What conclusions can you draw from reading this graph?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Standardized Test Preparation

EOG Prep

READING

Read each of the passages below. Then, answer the questions that follow each passage.

Passage 1 Scientists look for answers by asking questions. For instance, scientists have wondered if there is some relationship between Earth's core and Earth's magnetic field. To form their hypothesis, scientists started with what they knew: Earth has a dense, solid inner core and a molten outer core. They then created a computer model to <u>simulate</u> how Earth's magnetic field is generated. The model predicted that Earth's inner core spins in the same direction as the rest of the Earth but slightly faster than the surface. If that hypothesis is correct, it might explain how Earth's magnetic field is generated. But how could the researchers test the hypothesis? Because scientists couldn't drill down to the core, they had to get their information indirectly. They decided to track seismic waves created by earthquakes.

1. In the passage, what does *simulate* mean?

A to look or act like
B to process
C to calculate
D to predict

2. According to the passage, what do scientists wonder?

F if the Earth's inner core was molten
G if there was a relationship between Earth's core and Earth's magnetic field
H if the Earth had a solid outer core
I if computers could model the Earth's core

3. What did the model predict?

A The Earth's outer core is molten.
B The Earth's inner core is molten.
C The Earth's inner core spins in the same direction as the rest of the Earth.
D The Earth's outer core spins in the same direction as the rest of the Earth.

Passage 2 Scientists analyzed seismic data for a 30-year period. They knew that seismic waves traveling through the inner core along a north-south path travel faster than waves passing through it along an east-west line. Scientists searched seismic data records to see if the <u>orientation</u> of the "fast path" for seismic waves changed over time. They found that in the last 30 years, the direction of the "fast path" for seismic waves had indeed shifted. This is strong evidence that Earth's core does travel faster than the surface, and it strengthens the hypothesis that the spinning core creates Earth's magnetic field.

1. In the passage, what does *orientation* mean?

A speed
B direction
C magnetic field
D intensity

2. What evidence did scientists find?

F The Earth's core does travel faster than the surface.
G The "fast path" does not change.
H Seismic waves travel faster along an east-west line.
I The spinning core does not create the Earth's magnetic field.

3. What do scientists hypothesize about the Earth's magnetic field?

A It was found in the last 30 years.
B It travels faster along a north-south path.
C It is losing its strength.
D It is created by the spinning core.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

INTERPRETING GRAPHICS

The table below contains data that shows the relationship between volume and pressure. Use the table to answer the questions that follow.

Volume (L)	Pressure (kPa)
0.5	4,960
1.0	2,480
2.0	1,240
3.0	827

1. What is the pressure when the volume is 2.0 L?

A 4,960 kPa
B 2,480 kPa
C 1,240 kPa
D 827 kPa

2. What is the volume when the pressure is 827 kPa?

F 0.5 L
G 1.0 L
H 2.0 L
I 3.0 L

3. What is the change in pressure when the volume is increased from 0.5 L to 1.0 L?

A 4,960 kPa
B 2,480 kPa
C 1,240 kPa
D 0.50 kPa

4. Which of the following patterns best describes the data?

F When the volume is doubled, the pressure is tripled.
G When the volume is tripled, the pressure is cut in half.
H As the volume increases, the pressure remains the same.
I As the volume increases, the pressure decreases.

MATH

Read each question below, and choose the best answer.

1. The original design for a boat shows a rectangular shape that is 5 m long and 1.5 m wide. If the design is reduced to 3.4 m long and 1 m wide, by how much does the area of the boat decrease?

A 1.7 m^2
B 4.1 m^2
C 7.5 m^2
D 9.2 m^2

2. If *density* = *mass*/*volume,* what is the density of an object that has a mass of 50 g and a volume of 2.6 cm^3?

F 0.052 cm^3/g
G 19.2 g/cm^3
H 47.4 g/cm^3
I 130 g/cm^3

3. During a chemical change, two separate pieces of matter combined into one. The mass of the final product is 82 g. The masses of the original pieces must equal the final product's mass. What are the possible masses of the original pieces of matter?

A 2 g and 18 g
B 2 g and 41 g
C 12 g and 8 g
D 42 g and 40 g

4. An adult *Seismosaurus hallorum* weighs 82 tons. A baby *Seismosaurus hallorum* weighs 46 tons. The weight of the baby *Seismosaurus hallorum* is what percentage of the weight of the adult *Seismosaurus hallorum*?

F 24%
G 44%
H 56%
I 98%

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Science in Action

Science, Technology, and Society

A "Ship" That Flips?

Does your school's laboratory have doors on the floor or tables bolted sideways to the walls? A lab like this exists, and you can find it floating in the ocean. *FLIP,* or *Floating Instrument Platform*, is a 108 m long ocean research vessel that can tilt 90°. *FLIP* is towed to an area that scientists want to study. To flip the vessel, empty chambers within the vessel are filled with water. The *FLIP* begins tilting until almost all of the vessel is underwater. Having most of the vessel below the ocean's surface stabilizes the vessel against wind and waves. Scientists can collect accurate data from the ocean, even during a hurricane!

Social Studies ACTIVITY

Design your own *FLIP*. Make a map on poster board. Draw the layout of a living room, bathroom, and bedroom before your *FLIP* is tilted 90°. Include entrances and walkways to use when *FLIP* is not flipped.

Weird Science

It's Raining Fish and Frogs

What forms of precipitation have you seen fall from the sky? Rain, snow, hail, sleet, or fish? Wait a minute! Fish? Fish and frogs might not be a form of precipitation, but as early as the second century, they have been reported to fall from the sky during rainstorms. Scientists theorize that tornadoes or waterspouts that suck water into clouds can also suck up unsuspecting fish, frogs, or tadpoles that are near the surface of the water. After being sucked up into the clouds and carried a few miles, these reluctant travelers then rain down from the sky.

Language Arts ACTIVITY

WRITING SKILL You are a reporter for your local newspaper. On a rainy day in spring, while driving to work, you witness a downpour of frogs and fish. You pull off to the side of the road and interview other witnesses. Write an article describing this event for your local newspaper.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

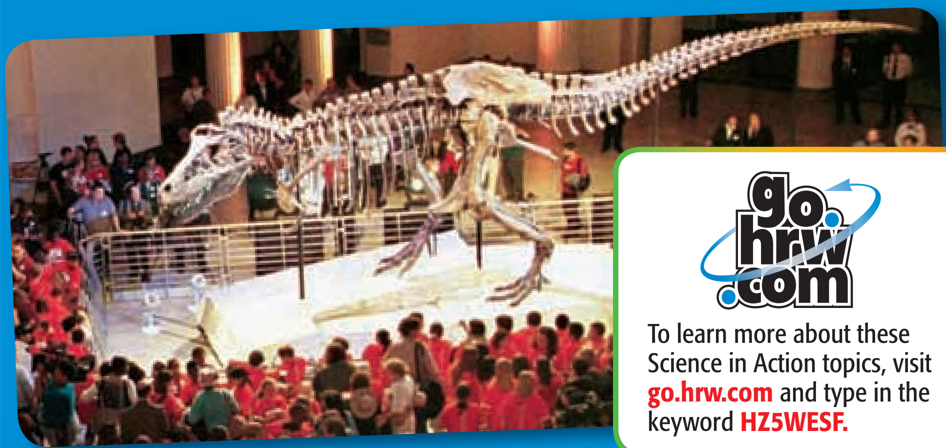
Careers

Sue Hendrickson

Paleontologist Could you imagine having a job in which you spent all day digging in the dirt? This is just one of Sue Hendrickson's job descriptions. But Hendrickson does not dig up flowers. Hendrickson is a paleontologist, and she digs up dinosaurs! Her most famous discovery is the bones of a *Tyrannosaurus rex*. *T. rex* is one of the largest meat-eating dinosaurs. It lived between 65 million and 85 million years ago. Walking tall at 6 m, *T. rex* was approximately 12.4 m long and weighed between 5 and 7 tons. Hendrickson's discovery is the most complete set of bones ever found of the *T. rex*. The dinosaur was named Sue to honor Hendrickson for her important find. From these bones, Hendrickson and other scientists have been able to learn more about the dinosaur, including how it lived millions of years ago. For example, Hendrickson and her team of scientists found the remains of Sue's last meal, part of a duck-billed, plant-eating dinosaur of the genus *Edmontosaurus* that weighed approximately 3.5 tons!

Math Activity

The *T. rex* named Sue weighed 7 tons and the *Edmontosaurus* dinosaur weighed 3.5 tons. How much smaller is *Edmontosaurus* than Sue? Express your answer as a percentage.



To learn more about these Science in Action topics, visit go.hrw.com and type in the keyword HZ5WESF.

Current Science

Check out Current Science® articles related to this chapter by visiting go.hrw.com. Just type in the keyword HZ5CS01.

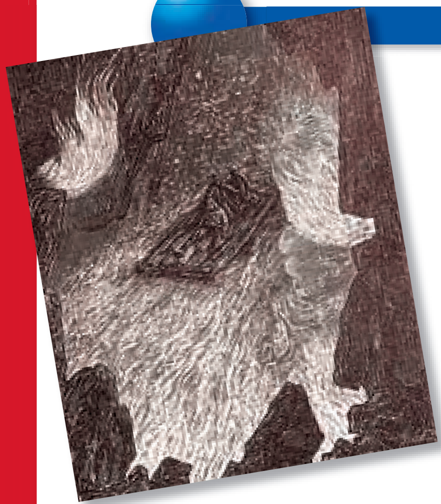
Copyright © by Holt, Rinehart and Winston. All rights reserved.

UNIT 1

TIMELINE

The Earth in Transition

In this unit, you will learn what a dynamic planet the Earth is. Earth's landmasses are changing position continuously as they travel across Earth's surface on tremendous blocks of rock. As these blocks collide with each other, mountain ranges are formed. As these blocks pull apart, magma is released from below, sometimes explosively in volcanic eruptions. When these blocks grind slowly past one another, long breaks in the Earth are created, where devastating earthquakes can take place. This timeline shows some of the events that have occurred as scientists have tried to understand our dynamic Earth.

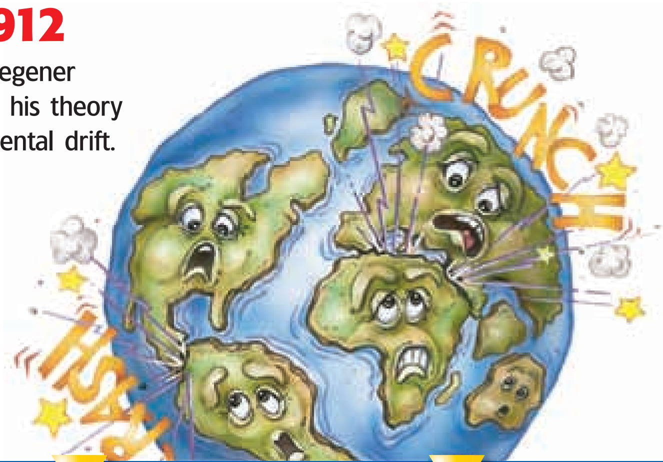


1864

Jules Verne's *A Journey to the Center of the Earth* is published. In this fictional story, the heroes enter and exit the Earth through volcanoes.

1912

Alfred Wegener proposes his theory of continental drift.

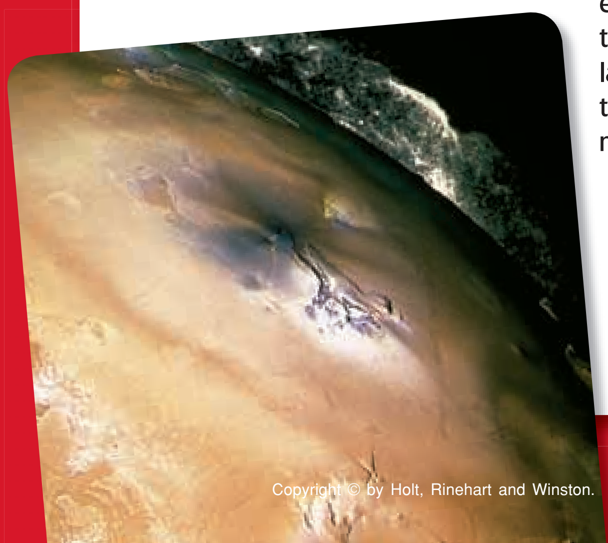


1979

Volcanoes are discovered on Io, one of Jupiter's moons.

1980

Mount St. Helens erupts after an earthquake triggers a landslide on the volcano's north face.



Io, one of Jupiter's moons

Copyright © by Holt, Rinehart and Winston. All rights reserved.

1883

When Krakatau erupts, more than 36,000 people are killed.

1896

Henry Ford builds his first car.

The Quadricycle, Henry Ford's first car

1906

San Francisco burns in the aftermath of an earthquake.

1935

Charles Richter devises a system of measuring the magnitude of earthquakes.

1951

Color television programming is introduced in the United States.

1962

A worldwide network of seismographs is established.

1982

Compact discs (CDs) and compact-disc players are made available to the public.

1994

An eight-legged robot named Dante II descends into the crater of an active volcano in Alaska.

Dante II

1997

The population of the Caribbean island of Montserrat dwindles to less than half its original size as frequent eruptions of the Soufriere Hills volcano force evacuations.

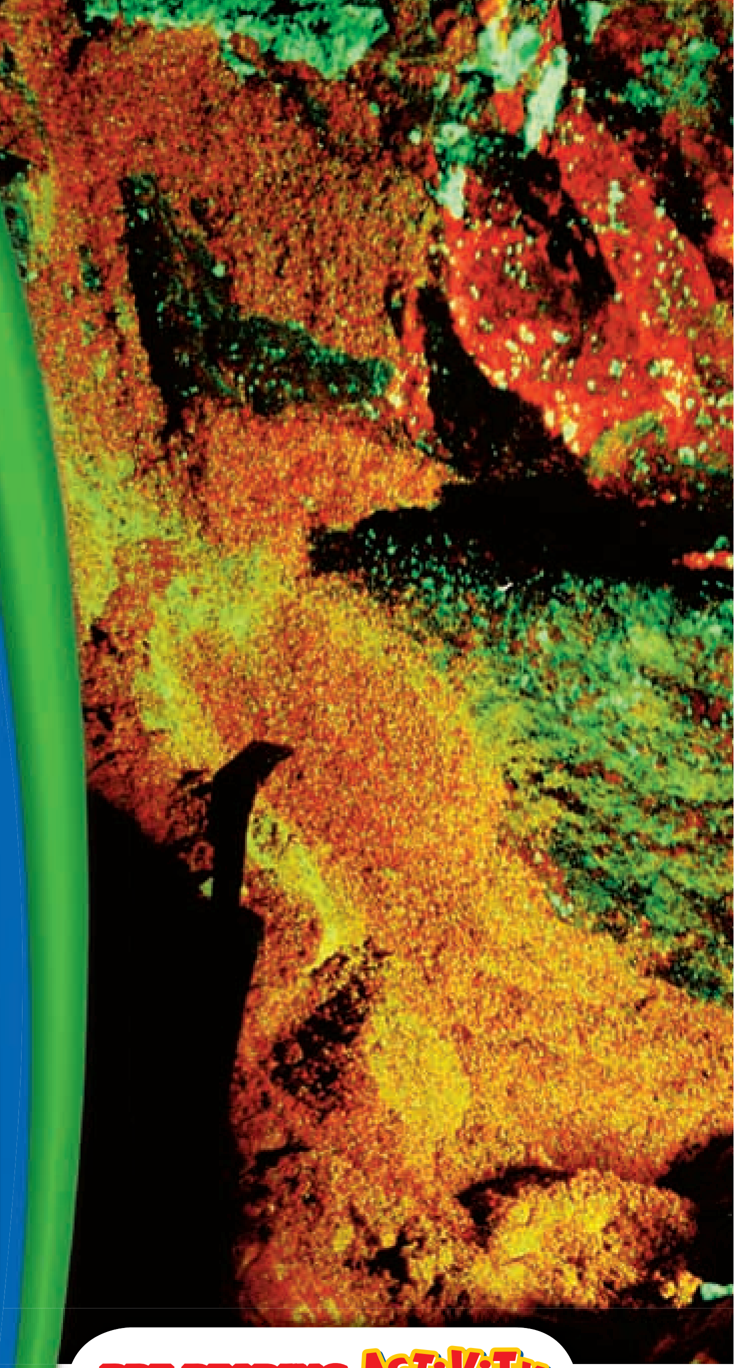
2003

An earthquake of magnitude 4.6 strikes Alabama. It is one of the largest earthquakes ever recorded for this area.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

2

Minerals of the Earth's Crust



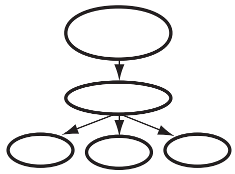
About the PHOTO

Fluorescence is the ability that some minerals have to glow under ultraviolet light. The beauty of mineral fluorescence is well represented at the Sterling Hill Mine in Franklin, New Jersey. In this picture taken at the mine, minerals in the rock glow as brightly as if they had been freshly painted by an artist.

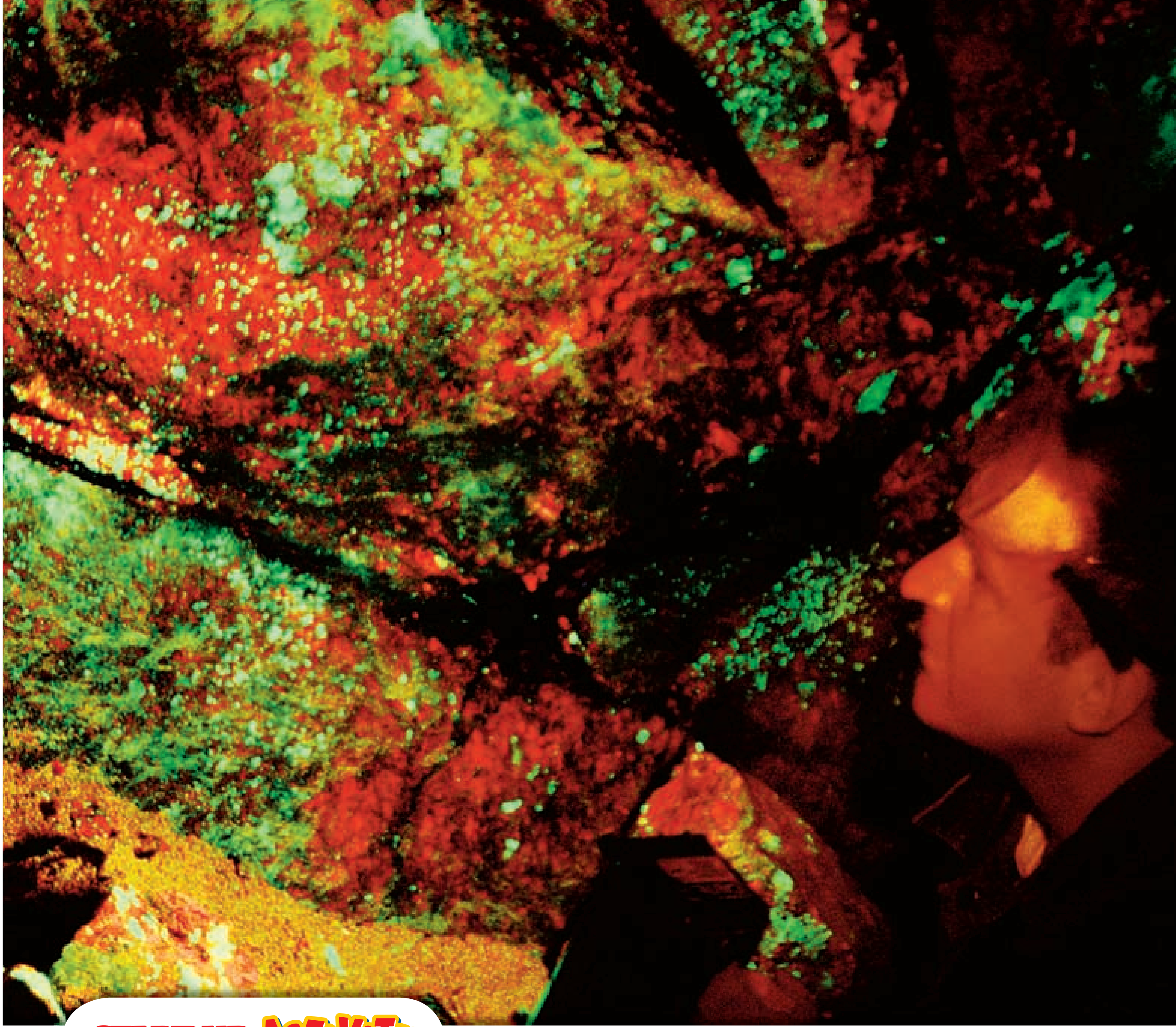
PRE-READING ACTIVITY

Graphic Organizer

Concept Map Before you read the chapter, create the graphic organizer entitled "Concept Map" described in the **Study Skills** section of the Appendix. As you read the chapter, fill in the concept map with details about minerals.



Copyright © by Holt, Rinehart and Winston. All rights reserved.



START-UP ACTIVITY

What Is Your Classroom Made Of?

One of the properties of minerals is that minerals are made from nonliving material. Complete the following activity to see if you can determine whether items in your classroom are made from living or nonliving materials.

Procedure

1. On a **sheet of paper,** make two columns. Label one column "Materials made from living things." Label the second column "Materials made from nonliving things."
2. Look around your classroom. Choose a variety of items to put on your list. Some items that you might select are your clothing, your desk, books, notebook paper, pencils, the classroom windows, doors, walls, the ceiling, and the floor.
3. With a partner, discuss each item that you have chosen. Decide into which column each item should be placed. Write down the reason for your decision.

Analysis

1. Are most of the items that you chose made of living or nonliving materials?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 1

What Is a Mineral?

You may think that all minerals look like gems. But, in fact, most minerals look more like rocks. Does this mean that minerals are the same as rocks? Well, not really. So, what's the difference?

For one thing, rocks are made of minerals, but minerals are not made of rocks. A **mineral** is a naturally formed, inorganic solid that has a definite crystalline structure.

READING WARM-UP

Objectives

- Describe the structure of minerals.
- Describe the two major groups of minerals.

Terms to Learn

mineral
element
compound
crystal
silicate mineral
nonsilicate mineral

READING STRATEGY

Paired Summarizing Read this section silently. In pairs, take turns summarizing the material. Stop to discuss ideas that seem confusing.

Mineral Structure

By answering the four questions in **Figure 1,** you can tell whether an object is a mineral. If you cannot answer "yes" to all four questions, you don't have a mineral. Three of the four questions may be easy to answer. The question about crystalline structure may be more difficult. To understand what crystalline structure is, you need to know a little about the elements that make up a mineral. **Elements** are pure substances that cannot be broken down into simpler substances by ordinary chemical means. All minerals contain one or more of the 92 naturally occurring elements.

Figure 1 *The answers to these four questions will determine whether an object is a mineral.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

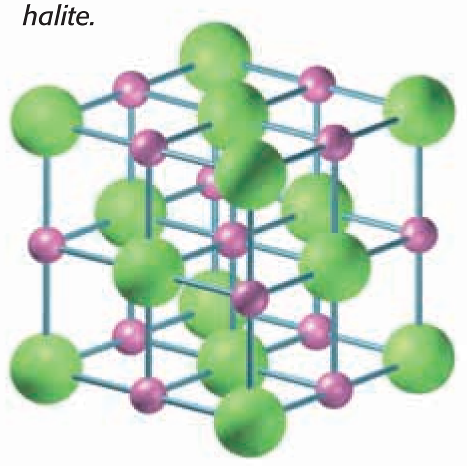
Atoms and Compounds

Each element is made of only one kind of atom. An *atom* is the smallest part of an element that has all the properties of that element. Like other substances, minerals are made up of atoms of one or more elements.

Most minerals are made of compounds of several different elements. A **compound** is a substance made of two or more elements that have been chemically joined, or bonded. Halite, NaCl, for example, is a compound of sodium, Na, and chlorine, Cl, as shown in **Figure 2.** A few minerals, such as gold and silver, are composed of only one element. A mineral that is composed of only one element is called a *native element.*

Reading Check **How does a compound differ from an element? (***See the Appendix for answers to Reading Checks.***)**

Figure 2 *When atoms of sodium (purple) and chlorine (green) join, they form a compound commonly known as rock salt, or the mineral halite.*



Crystals

Solid, geometric forms of minerals produced by a repeating pattern of atoms that is present throughout the mineral are called **crystals.** A crystal's shape is determined by the arrangement of the atoms within the crystal. The arrangement of atoms in turn is determined by the kinds of atoms that make up the mineral. Each mineral has a definite crystalline structure. All minerals can be grouped into crystal classes according to the kinds of crystals they form. **Figure 3** shows how the atomic structure of gold gives rise to cubic crystals.

mineral a naturally formed, inorganic solid that has a definite crystalline structure

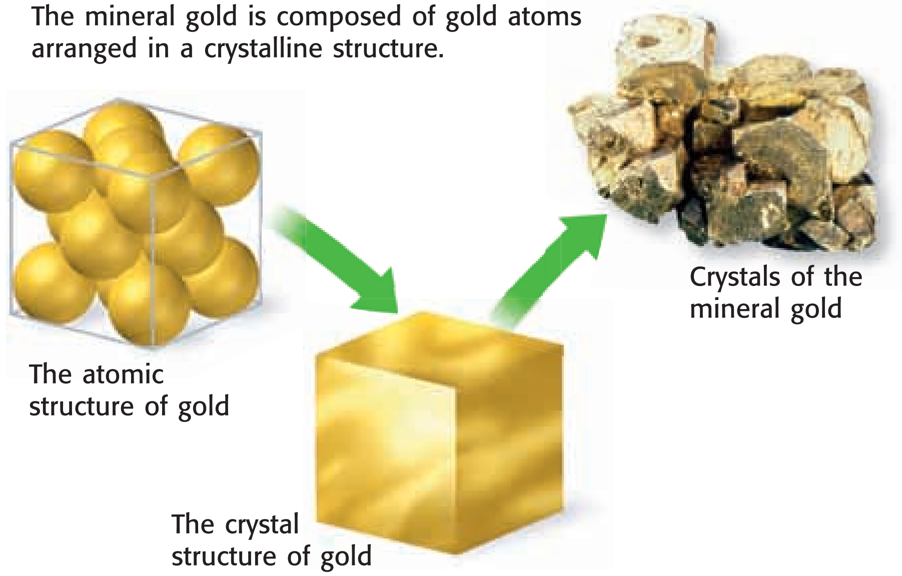
element a substance that cannot be separated or broken down into simpler substances by chemical means

compound a substance made up of atoms of two or more different elements joined by chemical bonds

crystal a solid whose atoms, ions, or molecules are arranged in a definite pattern

Figure 3 **Composition of the Mineral Gold**

The mineral gold is composed of gold atoms arranged in a crystalline structure.



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Two Groups of Minerals

The most common classification of minerals is based on chemical composition. Minerals are divided into two groups based on their chemical composition. These groups are the silicate minerals and the nonsilicate minerals.

Silicate Minerals

Silicon and oxygen are the two most common elements in the Earth's crust. Minerals that contain a combination of these two elements are called **silicate minerals.** Silicate minerals make up more than 90% of the Earth's crust. The rest of the Earth's crust is made up of nonsilicate minerals. Silicon and oxygen usually combine with other elements, such as aluminum, iron, magnesium, and potassium, to make up silicate minerals. Some of the more common silicate minerals are shown in **Figure 4.**

Nonsilicate Minerals

Minerals that do not contain a combination of the elements silicon and oxygen form a group called the **nonsilicate minerals.** Some of these minerals are made up of elements such as carbon, oxygen, fluorine, and sulfur. **Figure 5** on the following page shows the most important classes of nonsilicate minerals.

Reading Check **How do silicate minerals differ from nonsilicate minerals?**

CONNECTION TO Biology

WRITING SKILL **Magnetite** The mineral magnetite has a special property—it is magnetic. Scientists have found that some animals' brains contain magnetite. And scientists have shown that certain fish can sense magnetic fields because of the magnetite in the brains of these fish. The magnetite gives the fish a sense of direction. Using the Internet or another source, research other animals that have magnetite in their brains. Summarize your findings in a short essay.

silicate mineral a mineral that contains a combination of silicon, oxygen, and one or more metals

nonsilicate mineral a mineral that does not contain compounds of silicon and oxygen

Figure 4 **Common Silicate Minerals**

Quartz is the basic building block of many rocks.

Feldspar minerals are the main component of most rocks on the Earth's surface.

Mica minerals separate easily into sheets when they break. Biotite is one of several kinds of mica.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 5 Classes of Nonsilicate Minerals

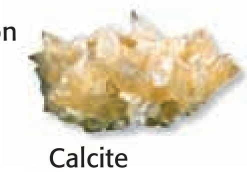
Native elements are minerals that are composed of only one element. Some examples are copper, Cu, gold, Au, and silver, Ag. Native elements are used in communications and electronics equipment.

Copper

Oxides are compounds that form when an element, such as aluminum or iron, combines chemically with oxygen. Oxide minerals are used to make abrasives, aircraft parts, and paint.

Corundum

Carbonates are minerals that contain combinations of carbon and oxygen in their chemical structure. We use carbonate minerals in cement, building stones, and fireworks.



Calcite

Sulfates are minerals that contain sulfur and oxygen, SO_4. Sulfates are used in cosmetics, toothpaste, cement, and paint.

Gypsum

Halides are compounds that form when fluorine, chlorine, iodine, or bromine combine with sodium, potassium, or calcium. Halide minerals are used in the chemical industry and in detergents.

Fluorite

Sulfides are minerals that contain one or more elements, such as lead, iron, or nickel, combined with sulfur. Sulfide minerals are used to make batteries, medicines, and electronic parts.

Galena

SECTION Review

Summary

- A mineral is a naturally formed, inorganic solid that has a definite crystalline structure.
- Minerals may be either elements or compounds.
- Mineral crystals are solid, geometric forms that are produced by a repeating pattern of atoms.
- Minerals are classified as either silicate minerals or nonsilicate minerals based on the elements of which they are composed.

Using Key Terms

1. In your own words, write a definition for each of the following terms: *element*, *compound*, and *mineral*.

Understanding Key Ideas

2. Which of the following minerals is a nonsilicate mineral?
   a. mica
   b. quartz
   c. gypsum
   d. feldspar
3. What is a crystal, and what determines a crystal's shape?
4. Describe the two major groups of minerals.

Math Skills

5. If there are approximately 3,600 known minerals and about 20 of the minerals are native elements, what percentage of all minerals are native elements?

Critical Thinking

6. **Applying Concepts** Explain why each of the following is not considered a mineral: water, oxygen, honey, and teeth.
7. **Applying Concepts** Explain why scientists consider ice to be a mineral.
8. **Making Comparisons** In what ways are sulfate and sulfide minerals the same. In what ways are they different?

SCILINKS® NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Gems

SciLinks code: HSM0640

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 2

Identifying Minerals

If you closed your eyes and tasted different foods, you could probably determine what the foods are by noting properties such as saltiness or sweetness. You can also determine the identity of a mineral by noting different properties.

In this section, you will learn about the properties that will help you identify minerals.

READING WARM-UP

Objectives

- Identify seven ways to determine the identity of minerals.
- Explain special properties of minerals.

Terms to Learn

luster	fracture
streak	hardness
cleavage	density

READING STRATEGY

Reading Organizer As you read this section, create an outline of the section. Use the headings from the section in your outline.

Color

The same mineral can come in a variety of colors. For example, in its purest state quartz is clear. Samples of quartz that contain various types of and various amounts of impurities, however, can be a variety of colors.

Besides impurities, other factors can change the appearance of minerals. The mineral pyrite, often called fool's gold, normally has a golden color. But if pyrite is exposed to air and water for a long period, it can turn brown or black. Because of factors such as impurities, color usually is not the best way to identify a mineral.

Luster

The way a surface reflects light is called **luster.** When you say an object is shiny or dull, you are describing its luster. Minerals have metallic, submetallic, or nonmetallic luster. If a mineral is shiny, it has a metallic luster. If the mineral is dull, its luster is either submetallic or nonmetallic. The different types of lusters are shown in **Figure 1.**

luster the way in which a mineral reflects light

Figure 1 Types of Mineral Luster

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Streak

The color of a mineral in powdered form is called the mineral's **streak.** A mineral's streak can be found by rubbing the mineral against a piece of unglazed porcelain called a *streak plate*. The mark left on the streak plate is the streak. The streak is a thin layer of powdered mineral. The color of a mineral's streak is not always the same as the color of the mineral sample. The difference between color and streak is shown in **Figure 2.** Unlike the surface of a mineral sample, the streak is not affected by air or water. For this reason, using streak is more reliable than using color in identifying a mineral.

Reading Check **Why is using streak more reliable in identifying a mineral than using color is?** (*See the Appendix for answers to Reading Checks.*)

Figure 2 *The color of the mineral hematite may vary, but hematite's streak is always red-brown.*

Cleavage and Fracture

Different types of minerals break in different ways. The way a mineral breaks is determined by the arrangement of its atoms. **Cleavage** is the tendency of some minerals to break along smooth, flat surfaces. **Figure 3** shows the cleavage patterns of the minerals mica and halite.

Fracture is the tendency of some minerals to break unevenly along curved or irregular surfaces. One type of fracture is shown in **Figure 4.**

streak the color of the powder of a mineral

cleavage the splitting of a mineral along smooth, flat surfaces

fracture the manner in which a mineral breaks along either curved or irregular surfaces

Figure 3 *Cleavage varies with mineral type.*

Mica breaks easily into distinct sheets.

Halite breaks at 90° angles in three directions.

Figure 4 *This sample of quartz shows a curved fracture pattern called* conchoidal fracture *(kahn KOYD uhl FRAK chuhr).*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 5 **Mohs Hardness Scale**

A mineral's number indicates its relative hardness. The scale ranges from 1, which is the softest, to 10, which is the hardest. A mineral of a given hardness will scratch any mineral that is softer than it is.

hardness a measure of the ability of a mineral to resist scratching

density the ratio of the mass of a substance to the volume of the substance

Hardness

A mineral's resistance to being scratched is called **hardness**. To determine the hardness of minerals, scientists use *Mohs hardness scale,* shown in **Figure 5.** Notice that talc has a rating of 1 and diamond has a rating of 10. The greater a mineral's resistance to being scratched is, the higher the mineral's rating is. To identify a mineral by using Mohs scale, try to scratch the surface of a mineral with the edge of one of the 10 reference minerals. If the reference mineral scratches your mineral, the reference mineral is harder than your mineral.

Reading Check **How would you determine the hardness of an unidentified mineral sample?**

Density

If you pick up a golf ball and a table-tennis ball, which will feel heavier? Although the balls are of similar size, the golf ball will feel heavier because it is denser. **Density** is the measure of how much matter is in a given amount of space. In other words, density is a ratio of an object's mass to its volume. Density is usually measured in grams per cubic centimeter. Because water has a density of 1 g/cm^3, it is used as a reference point for other substances. The ratio of an object's density to the density of water is called the object's *specific gravity*. The specific gravity of gold, for example, is 19. So, gold has a density of 19 g/cm^3. In other words, there is 19 times more matter in 1 cm^3 of gold than in 1 cm^3 of water.

Quick Lab

Scratch Test

1. You will need a **penny,** a **pencil,** and your **fingernail.** Which one of these three materials is the hardest?
2. Use your fingernail to try to scratch the graphite at the tip of a pencil.
3. Now try to scratch the penny with your fingernail.
4. Rank the three materials in order from softest to hardest.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Special Properties

Some properties are particular to only a few types of minerals. The properties shown in **Figure 6** can help you quickly identify the minerals shown. To identify some properties, however, you will need specialized equipment.

Figure 6 **Special Properties of Some Minerals**

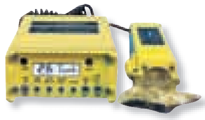
Fluorescence Calcite and fluorite glow under ultraviolet light. The same fluorite sample is shown in ultraviolet light (top) and in white light (bottom).

Chemical Reaction Calcite will become bubbly, or "fizz," when a drop of weak acid is placed on it.

Optical Properties A thin, clear piece of calcite placed over an image will cause a double image.

Magnetism Both magnetite and pyrrhotite are natural magnets that attract iron.

Taste Halite has a salty taste.



Radioactivity Minerals that contain radium or uranium can be detected by a Geiger counter.

SECTION Review

Summary

- Properties that can be used to identify minerals are color, luster, streak, cleavage, fracture, hardness, and density.
- Some minerals can be identified by special properties they have, such as taste, magnetism, fluorescence, radioactivity, chemical reaction, and optical properties.

Using Key Terms

1. Use each of the following terms in a separate sentence: *luster*, *streak*, and *cleavage*.

Understanding Key Ideas

2. Which of the following properties of minerals is expressed in numbers?
   a. fracture
   b. cleavage
   c. hardness
   d. streak
3. How do you determine a mineral's streak?
4. Briefly describe the special properties of minerals.

Math Skills

5. If a mineral has a specific gravity of 5.5, how much more matter is there in 1 cm^3 of this mineral than in 1 cm^3 of water?

Critical Thinking

6. **Applying Concepts** What properties would you use to determine whether two mineral samples are different minerals?
7. **Applying Concepts** If a mineral scratches calcite but is scratched by apatite, what is the mineral's hardness?
8. **Analyzing Methods** What would be the easiest way to identify calcite?

SCILINKS® NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Identifying Minerals
SciLinks code: HSM0782

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 3

The Formation, Mining, and Use of Minerals

If you wanted to find a mineral, where do you think you would look?

READING WARM-UP

Objectives

- Describe the processes that form minerals.
- Compare the two types of mining.
- Describe different economic uses for minerals.
- List six common minerals that are found in North Carolina.

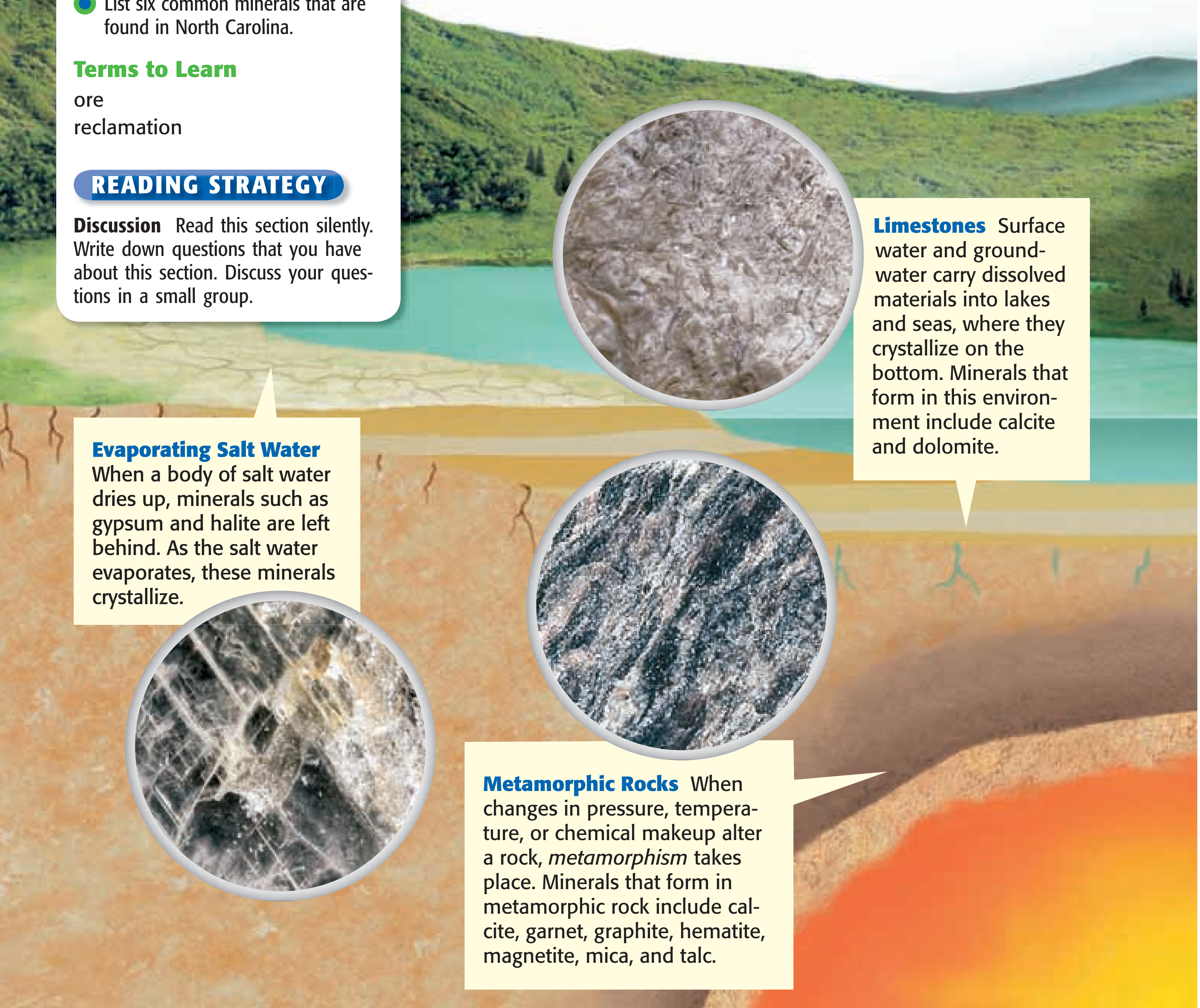
Terms to Learn

ore
reclamation

READING STRATEGY

Discussion Read this section silently. Write down questions that you have about this section. Discuss your questions in a small group.

Minerals form in a variety of environments in the Earth's crust. Each of these environments has a different set of physical and chemical conditions. Therefore, the environment in which a mineral forms determines the mineral's properties. Environments in which minerals form may be on or near the Earth's surface or deep beneath the Earth's surface.



Limestones Surface water and groundwater carry dissolved materials into lakes and seas, where they crystallize on the bottom. Minerals that form in this environment include calcite and dolomite.

Evaporating Salt Water When a body of salt water dries up, minerals such as gypsum and halite are left behind. As the salt water evaporates, these minerals crystallize.

Metamorphic Rocks When changes in pressure, temperature, or chemical makeup alter a rock, *metamorphism* takes place. Minerals that form in metamorphic rock include calcite, garnet, graphite, hematite, magnetite, mica, and talc.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

INTERNET ACTIVITY

For another activity related to this chapter, go to go.hrw.com and type in the keyword **HZ5MINW.**

Hot-Water Solutions Groundwater works its way downward and is heated by magma. It then reacts with minerals to form a hot liquid solution. Dissolved metals and other elements crystallize out of the hot fluid to form new minerals. Gold, copper, sulfur, pyrite, and galena form in such hot-water environments.

Pegmatites As magma moves upward, it can form teardrop-shaped bodies called *pegmatites.* The mineral crystals in pegmatites become extremely large, sometimes growing to several meters across! Many gemstones, such as topaz and tourmaline, form in pegmatites.

Plutons As magma rises upward through the crust, it sometimes stops moving before it reaches the surface and cools slowly, forming millions of mineral crystals. Eventually, the entire magma body solidifies to form a *pluton.* Mica, feldspar, magnetite, and quartz are some of the minerals that form from magma.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

MATH PRACTICE

Surface Coal Mining

Producing 1 metric ton of coal requires that up to 30 metric tons of earth be removed first. Some surface coal mines produce up to 50,000 metric tons of coal per day. How many metric tons of earth might have to be removed in order to mine 50,000 metric tons of coal?

ore a natural material whose concentration of economically valuable minerals is high enough for the material to be mined profitably

Mining

Many kinds of rocks and minerals must be mined to extract the valuable elements they contain. Geologists use the term **ore** to describe a mineral deposit large enough and pure enough to be mined for profit. Rocks and minerals are removed from the ground by one of two methods—surface mining or subsurface mining. The method miners choose depends on how close to the surface or how far down in the Earth the mineral is located.

Surface Mining

When mineral deposits are located at or near the surface of the Earth, surface-mining methods are used to remove the minerals. Types of surface mines include open pits, surface coal mines, and quarries.

Open-pit mining is used to remove large, near-surface deposits of economically important minerals such as gold and copper. As shown in **Figure 1,** ore is mined downward, layer by layer, in an open-pit mine. Explosives are often used to break up the ore. The ore is then loaded into haul trucks and transported from the mine for processing. Quarries are open pits that are used to mine building stone, crushed rock, sand, and gravel. Coal that is near the surface is removed by surface coal mining. Surface coal mining is sometimes known as strip mining because the coal is removed in strips that may be as wide as 50 m and as long as 1 km.

Figure 1 *In open-pit mines, the ore is mined downward in layers. The stair-step excavation of the walls keeps the sides of the mine from collapsing. Giant haul trucks (inset) are used to transport ore from the mine.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

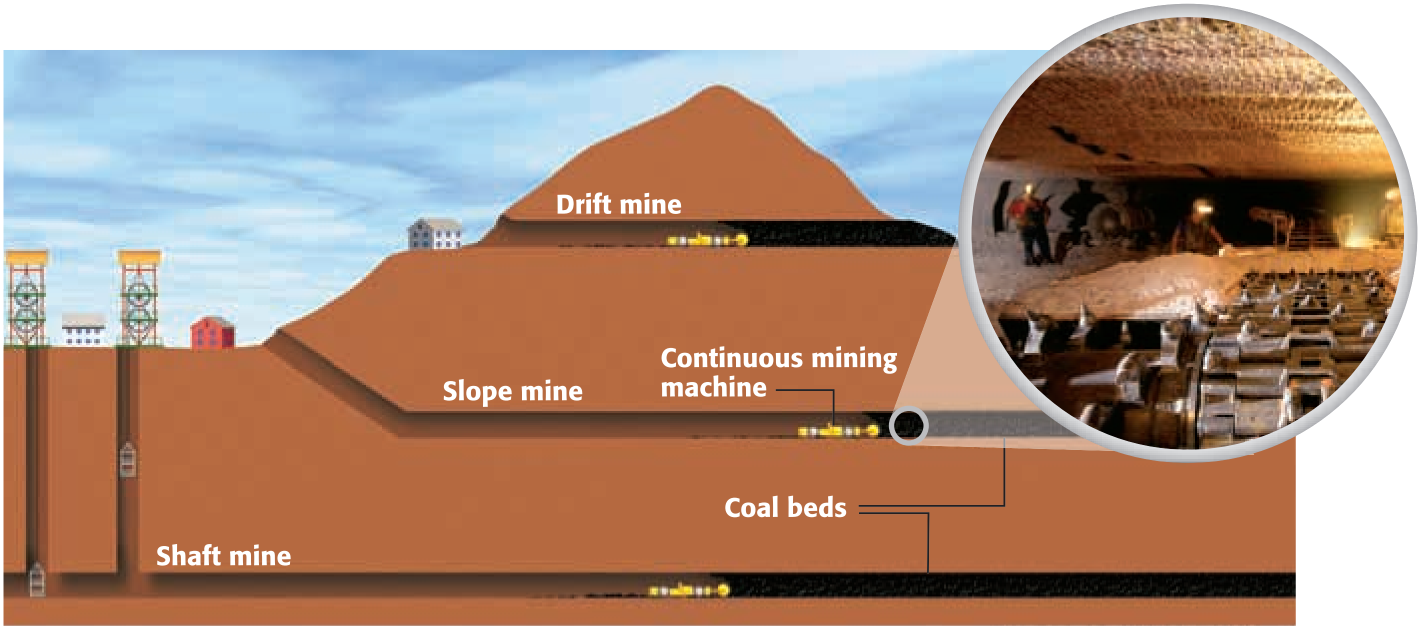


Figure 2 *Subsurface mining is the removal of minerals or other materials from deep within the Earth. Passageways must be dug underground to reach the ore. Machines such as continuous mining machines (inset) are used to mine ore in subsurface mines.*

Subsurface Mining

Subsurface mining methods are used when mineral deposits are located too deep within the Earth to be surface mined. Subsurface mining often requires that passageways be dug into the Earth to reach the ore. As shown in **Figure 2,** these passageways may be dug horizontally or at an angle. If a mineral deposit extends deep within the Earth, however, a vertical shaft is sunk. This shaft may connect a number of passageways that intersect the ore at different levels.

Reading Check **Compare surface and subsurface mining.** (*See the Appendix for answers to Reading Checks.*)

reclamation the process of returning land to its original condition after mining is completed

Responsible Mining

Mining gives us the minerals we need, but it may also create problems. Mining can destroy or disturb the habitats of plants and animals. Also, the waste products from a mine may get into water sources, which pollutes surface water and groundwater.

Mine Reclamation

One way to reduce the potential harmful effects of mining is to return the land to its original state after the mining is completed. The process by which land used for mining is returned to its original state or better is called **reclamation.** Reclamation of mined public and private land has been required by law since the mid-1970s. Another way to reduce the effects of mining is to reduce our need for minerals. We reduce our need for minerals by recycling many of the mineral products that we currently use, such as aluminum.

SCHOOL to HOME

Recycling Minerals at Home

With your parent, locate products in your home that are made of minerals. Decide which of these products could be recycled. In your **science journal,** make a list of the products that could be recycled to save minerals.

ACTIVITY

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Table 1 Common Uses of Minerals	
Mineral	**Uses**
Copper	electrical wire, plumbing, coins
Diamond	jewelry, cutting tools, drill bits
Galena	batteries, ammunition
Gibbsite	cans, foil, appliances, utensils
Gold	jewelry, computers, spacecraft, dentistry
Gypsum	wallboards, plaster, cement
Halite	nutrition, highway de-icer, water softener
Quartz	glass, computer chips
Silver	photography, electronics products, jewelry
Sphalerite	jet aircraft, spacecraft, paints

The Use of Minerals

As **Table 1** shows, some minerals are of major economic and industrial importance. Some minerals can be used just as they are. Other minerals must be processed to get the element or elements that the minerals contain. **Figure 3** is a map that shows minerals of economic and industrial importance that are found in North Carolina.

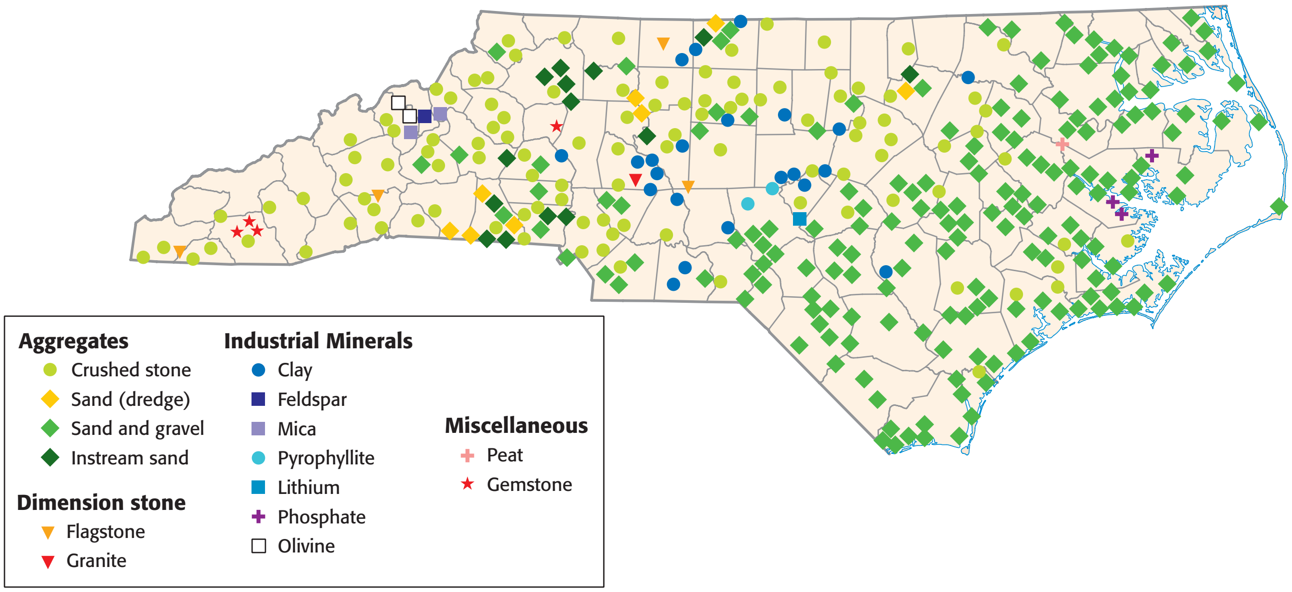
Metallic Minerals

Some minerals are metallic. Metallic minerals have shiny surfaces, do not let light pass through them, and are good conductors of heat and electricity. Metallic minerals can be processed into metals that are strong and do not rust. Other metals can be pounded or pressed into various shapes or stretched thinly without breaking. These properties make metals desirable for use in aircraft, automobiles, communications and electronic equipment, and spacecraft. Examples of metallic minerals that have many industrial uses are gold, silver, and copper.

Nonmetallic Minerals

Other minerals are nonmetals. Nonmetallic minerals have shiny or dull surfaces, may let light pass through them, and are good insulators of electricity. Nonmetallic minerals are some of the most widely used minerals in industry. For example, calcite is a major component of concrete, which is used in building roads, buildings, bridges, and other structures. Industrial sand and gravel, or silica, have uses that range from glassmaking to producing computer chips.

Figure 3 Economically Important Minerals of North Carolina



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Gemstones

Some nonmetallic minerals, called *gemstones*, are highly valued for their beauty and rarity rather than for their usefulness. Important gemstones include diamond, ruby, sapphire, emerald, aquamarine, topaz, and tourmaline. An example of a diamond is shown in **Figure 4.** Color is the most important characteristic of a gemstone. The more attractive the color is, the more valuable the gem is. Gemstones must also be durable. That is, they must be hard enough to be cut and polished. The mass of a gemstone is expressed in a unit known as a *carat*. One carat is equal to 200 mg.

Reading Check **In your own words, define the term *gemstone*.**

Figure 4 *The Cullinan diamond, at the center of this scepter, is part of the largest diamond ever found.*

SECTION Review

Summary

- Environments in which minerals form may be located at or near the Earth's surface or deep below the surface.
- The two types of mining are surface mining and subsurface mining.
- Two ways to reduce the effects of mining are the reclamation of mined land and the recycling of mineral products.
- Some metallic and nonmetallic minerals have many important economic and industrial uses.

Using Key Terms

Complete each of the following sentences by choosing the correct term from the word bank.

ore reclamation

1. _____ is the process of returning land to its original condition after mining is completed.
2. _____ is the term used to describe a mineral deposit that is large enough and pure enough to be mined for profit.

Understanding Key Ideas

3. Which of the following conditions is NOT important in the formation of minerals?
   a. presence of groundwater
   b. evaporation
   c. volcanic activity
   d. wind
4. What are the two main types of mining, and how do they differ?
5. List some economic uses of minerals.
6. List six common minerals found in North Carolina.

Math Skills

7. A diamond cutter has a raw diamond that weighs 19.5 carats and from which two 5-carat diamonds will be cut. How much did the raw diamond weigh in milligrams? How much will each of the two cut diamonds weigh in milligrams?

Critical Thinking

8. **Analyzing Ideas** How does reclamation protect the environment around a mine?
9. **Applying Concepts** Suppose you find a mineral crystal that is as tall as you are. What kinds of environmental factors would cause such a crystal to form?

SCILINKS® NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Mining Minerals
SciLinks code: HSM0968

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Using Scientific Methods

Skills Practice Lab

OBJECTIVES

Calculate the density and specific gravity of a mineral.

Explain how density and specific gravity can be used to identify a mineral specimen.

MATERIALS

- balance
- beaker, 400 mL
- galena sample
- pyrite sample
- ring stand
- spring scale
- string
- water, 400 mL

SAFETY

Is It Fool's Gold? A Dense Situation

Have you heard of fool's gold? Maybe you've seen a piece of it. This mineral is actually pyrite, and it was often passed off as real gold. However, there are simple tests that you can do to keep from being tricked. Minerals can be identified by their properties. Some properties, such as color, vary from sample to sample. Other properties, such as density and specific gravity, remain consistent across samples. In this activity, you will try to verify the identity of some mineral samples.

Ask a Question

1. How can I determine if an unknown mineral is not gold or silver?

Form a Hypothesis

2. Write a hypothesis that is a possible answer to the question above. Explain your reasoning.

Test the Hypothesis

3. Copy the data table. Use it to record your observations.

Observation Chart

Measurement	Galena	Pyrite
Mass in air (g)		
Weight in air (N)		
Volume of mineral (mL)		
Weight in water (N)		

DO NOT WRITE IN BOOK

4. Find the mass of each sample by laying the mineral on the balance. Record the mass of each sample in your data table.
5. Attach the spring scale to the ring stand.
6. Tie a string around the sample of galena, and leave a loop at the loose end. Suspend the galena from the spring scale, and find its mass and weight in air. Do not remove the sample from the spring scale yet. Enter these data in your data table.

Galena

Pyrite

Copyright © by Holt, Rinehart and Winston. All rights reserved.

7. Fill a beaker halfway with water. Record the beginning volume of water in your data table.
8. Carefully lift the beaker around the galena until the mineral is completely submerged. Be careful not to splash any water out of the beaker! Do not allow the mineral to touch the beaker.
9. Record the new volume and weight in your data table.
10. Subtract the original volume of water from the new volume to find the amount of water displaced by the mineral. This is the volume of the mineral sample itself. Record this value in your data table.
11. Repeat steps 6–10 for the sample of pyrite.

Analyze the Results

1. **Constructing Tables** Copy the data table below. (Note: 1 mL = 1 cm^3)

Density Data Table		
Mineral	**Density (g/cm^3)**	**Specific gravity**
Silver	10.5	10.5
Galena	DO NOT WRITE IN BOOK	
Pyrite		
Gold	19.0	19.0

2. **Organizing Data** Use the following equations to calculate the density and specific gravity of each mineral, and record your answers in your data table.

$$\textit{density} = \frac{\textit{mass in air}}{\textit{volume}}$$

$$\textit{specific gravity} = \frac{\textit{weight in air}}{\textit{weight in air} - \textit{weight in water}}$$

Draw Conclusions

3. **Drawing Conclusions** The density of pure gold is 19 g/cm^3. How can you use this information to prove that your sample of pyrite is not gold?
4. **Drawing Conclusions** The density of pure silver is 10.5 g/cm^3. How can you use this information to prove that your sample of galena is not silver?
5. **Applying Conclusions** If you found a gold-colored nugget, how could you find out if the nugget was real gold or fool's gold?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Chapter Review

USING KEY TERMS

1 Use each of the following terms in a separate sentence: *element, compound,* and *mineral*.

For each pair of terms, explain how the meanings of the terms differ.

2 *color* and *streak*

3 *mineral* and *ore*

4 *silicate mineral* and *nonsilicate mineral*

UNDERSTANDING KEY IDEAS

Multiple Choice

5 Which of the following properties of minerals does Mohs scale measure?

a. luster
b. hardness
c. density
d. streak

6 Pure substances that cannot be broken down into simpler substances by ordinary chemical means are called

a. molecules.
b. elements.
c. compounds.
d. crystals.

7 Which of the following properties is considered a special property that applies to only a few minerals?

a. luster
b. hardness
c. taste
d. density

8 Silicate minerals contain a combination of the elements

a. sulfur and oxygen.
b. carbon and oxygen.
c. iron and oxygen.
d. silicon and oxygen.

9 The process by which land used for mining is returned to its original state is called

a. recycling.
b. regeneration.
c. reclamation.
d. renovation.

10 Which of the following minerals is an example of a gemstone?

a. mica
b. diamond
c. gypsum
d. copper

Short Answer

11 Compare surface and subsurface mining.

12 Explain the four characteristics of a mineral.

13 Describe two environments in which minerals form.

14 List two uses for metallic minerals and two uses for nonmetallic minerals.

15 Describe two ways to reduce the effects of mining.

16 Describe three special properties of minerals.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

CRITICAL THINKING

17 **Concept Mapping** Use the following terms to create a concept map: *minerals, calcite, silicate minerals, gypsum, carbonates, nonsilicate minerals, quartz,* and *sulfates*.

18 **Making Inferences** Imagine that you are trying to determine the identity of a mineral. You decide to do a streak test. You rub the mineral across the streak plate, but the mineral does not leave a streak. Has your test failed? Explain your answer.

19 **Applying Concepts** Why would cleavage be important to gem cutters, who cut and shape gemstones?

20 **Applying Concepts** Imagine that you work at a jeweler's shop and someone brings in some gold nuggets for sale. You are not sure if the nuggets are real gold. Which identification tests would help you decide whether the nuggets are gold?

21 **Identifying Relationships** Suppose you are in a desert. You are walking across the floor of a dry lake, and you see crusts of cubic halite crystals. How do you suppose the halite crystals formed? Explain your answer.

INTERPRETING GRAPHICS

The table below shows the temperatures at which various minerals melt. Use the table below to answer the questions that follow.

Melting Points of Various Minerals

Mineral	Melting Point (°C)
Mercury	−39
Sulfur	+113
Halite	801
Silver	961
Gold	1,062
Copper	1,083
Pyrite	1,171
Fluorite	1,360
Quartz	1,710
Zircon	2,500

22 According to the table, what is the approximate difference in temperature between the melting points of the mineral that has the lowest melting point and the mineral that has the highest melting point?

23 Which of the minerals listed in the table do you think is a liquid at room temperature?

24 Pyrite is often called *fool's gold*. Using the information in the table, how could you determine if a mineral sample is pyrite or gold?

25 Convert the melting points of the minerals shown in the table from degrees Celsius to degrees Fahrenheit. Use the formula $°F = (9/5 \times °C) + 32$.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Standardized Test Preparation

EOG Prep

READING

Read each of the passages below. Then, answer the questions that follow each passage.

Passage 1 In North America, copper was mined at least 6,700 years ago by the ancestors of the Native Americans who live on Michigan's upper peninsula. Much of this mining took place on Isle Royale, an island in Lake Superior. These ancient people removed copper from the rock by using stone hammers and wedges. The rock was sometimes heated first to make breaking it up easier. Copper that was mined was used to make jewelry, tools, weapons, fish hooks, and other objects. These objects were often marked with designs. The Lake Superior copper was traded over long distances along ancient trade routes. Copper objects have been found in Ohio, Florida, the Southwest, and the Northwest.

1. In the passage, what does *ancient* mean?
- **A** young
- **B** future
- **C** modern
- **D** early

2. According to the passage, what did the ancient copper miners do?
- **F** They mined copper in Ohio, Florida, the Southwest, and the Northwest.
- **G** They mined copper by cooling the rock in which the copper was found.
- **H** They mined copper by using stone tools.
- **I** They mined copper for their use only.

3. Which of the following statements is a fact according to the passage?
- **A** Copper could be shaped into different objects.
- **B** Copper was unknown outside of Michigan's upper peninsula.
- **C** Copper could be mined easily from the rock in which it was found.
- **D** Copper could not be marked with designs.

Passage 2 Most mineral names end in *-ite*. The practice of so naming minerals dates back to the ancient Romans and Greeks, who added *-ites* and *-itis* to common words to indicate a color, a use, or the chemistry of a mineral. More recently, mineral names have been used to honor people, such as scientists, mineral collectors, and even rulers of countries. Other minerals have been named after the place where they were discovered. These place names include mines, quarries, hills, mountains, towns, regions, and even countries. Finally, some minerals have been named after gods in Greek, Roman, and Scandinavian mythology.

1. In the passage, what does *practice* mean?
- **A** skill
- **B** custom
- **C** profession
- **D** use

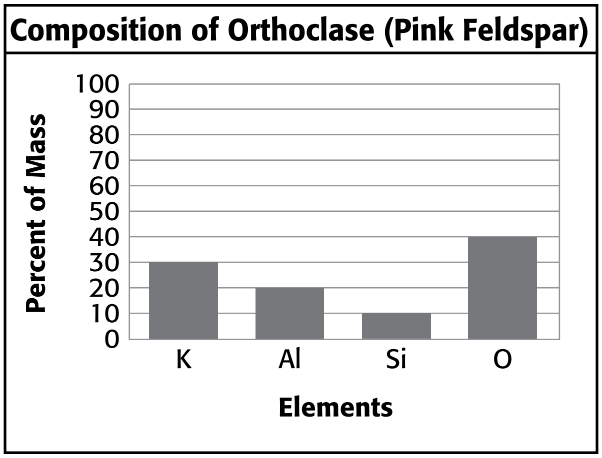
2. According to the passage, the ancient Greeks and Romans did not name minerals after what?
- **F** colors
- **G** chemical properties
- **H** people
- **I** uses

3. Which of the following statements is a fact according to the passage?
- **A** Minerals are sometimes named for the country in which they are discovered.
- **B** Minerals are never named after their collectors.
- **C** All mineral names end in *-ite*.
- **D** All of the known minerals were named by the Greeks and Romans.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

INTERPRETING GRAPHICS

A sample of feldspar was analyzed to find out what it was made of. The graph below shows the results of the analysis. Use the graph below to answer the questions that follow.



1. The sample consists of four elements: potassium, K, aluminum, Al, silicon, Si, and oxygen, O. Which element makes up the largest percentage of your sample?

A potassium
B aluminum
C silicon
D oxygen

2. Silicate minerals, such as feldspar, contain a combination of silicon and oxygen. What percentage of your sample is composed of silicon and oxygen combined?

F 30%
G 40%
H 50%
I 70%

3. If your sample has a mass of 10 g, how many grams of oxygen does it contain?

A 1 g
B 2 g
C 4 g
D 8 g

4. Your sample of orthoclase has a hardness of 6. Which of the following minerals will scratch your sample?

F gypsum
G corundum
H calcite
I apatite

MATH

Read each question below, and choose the best answer.

1. Gold classified as 24-karat is 100% gold. Gold classified as 18-karat is 18 parts gold and 6 parts another, similar metal. The gold is therefore 18/24, or 3/4, pure. What is the percentage of pure gold in 18-karat gold?

A 10%
B 25%
C 50%
D 75%

2. Gold's specific gravity is 19. Pyrite's specific gravity is 5. What is the difference in the specific gravities of gold and pyrite?

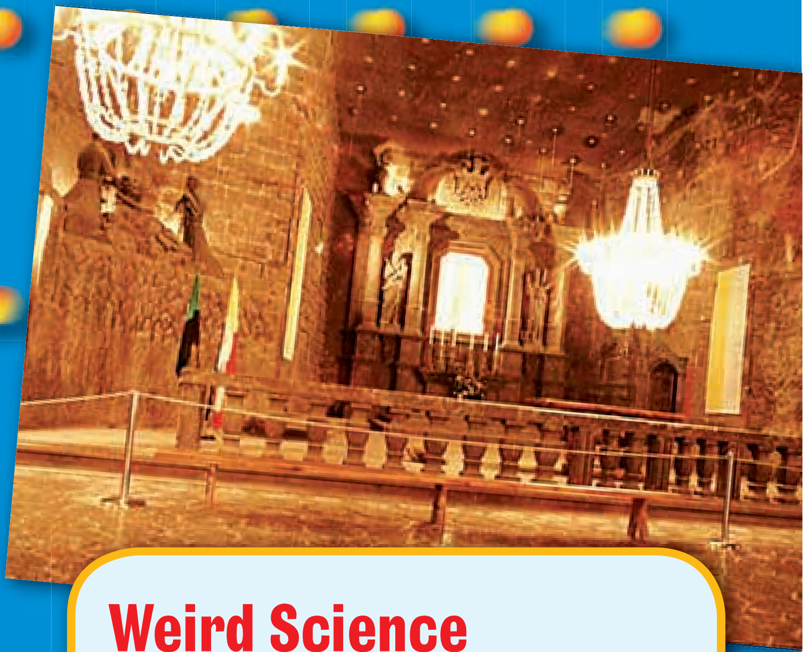
F 8 g/cm^3
G 10 g/cm^3
H 12 g/cm^3
I 14 g/cm^3

3. In a quartz crystal, there is one silicon atom for every two oxygen atoms. So, the ratio of silicon atoms to oxygen atoms is 1:2. If there were 8 million oxygen atoms in a sample of quartz, how many silicon atoms would there be in the sample?

A 2 million
B 4 million
C 8 million
D 16 million

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Science in Action



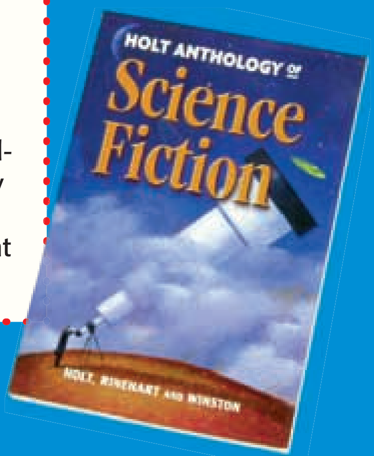
Science Fiction

"The Metal Man" by Jack Williamson

In a dark, dusty corner of Tyburn College Museum stands a life-sized statue of a man. Except for its strange greenish color, the statue looks quite ordinary. But if you look closely, you will see the perfect detail of the hair and skin. On the statue's chest, you will also see a strange mark—a dark crimson shape with six sides. No one knows how the statue ended up in the dark corner. But most people in Tyburn believe that the metal man is, or once was, Professor Thomas Kelvin of Tyburn College's geology department. Read for yourself the strange story of Professor Kelvin and the Metal Man, which is in the *Holt Anthology of Science Fiction*.

Language Arts Activity

WRITING SKILL Read "The Metal Man" by Jack Williamson. Write a short essay explaining how the ideas in the story are related to what you are learning.



Weird Science

Wieliczka Salt Mine

Imagine an underground city that is made entirely of salt. Within the city are churches, chapels, rooms of many kinds, and salt lakes. Sculptures of biblical scenes, saints, and famous historical figures carved from salt are found throughout the city. Even chandeliers of salt hang from the ceilings. Such a city is located 16 km southeast of Krakow, Poland, inside the Wieliczka (VEE uh LEETS kuh) Salt Mine. As the mine grew over the past 700 years, it turned into an elaborate underground city. Miners constructed chapels to patron saints so they could pray for a safe day in the mine. Miners also developed superstitions about the mine. So, images that were meant to bring good luck were carved in salt. In 1978, the mine was added to UNESCO's list of endangered world heritage sites. Many of the sculptures in the mine have begun to dissolve because of the humidity in the air. Efforts to save the treasures in the mine from further damage were begun in 1996.

Social Studies Activity

WRITING SKILL Research some aspect of the role of salt in human history. For example, subjects might include the Saharan and Tibetan salt trade or the use of salt as a form of money in ancient Poland. Report your findings in a one-page essay.

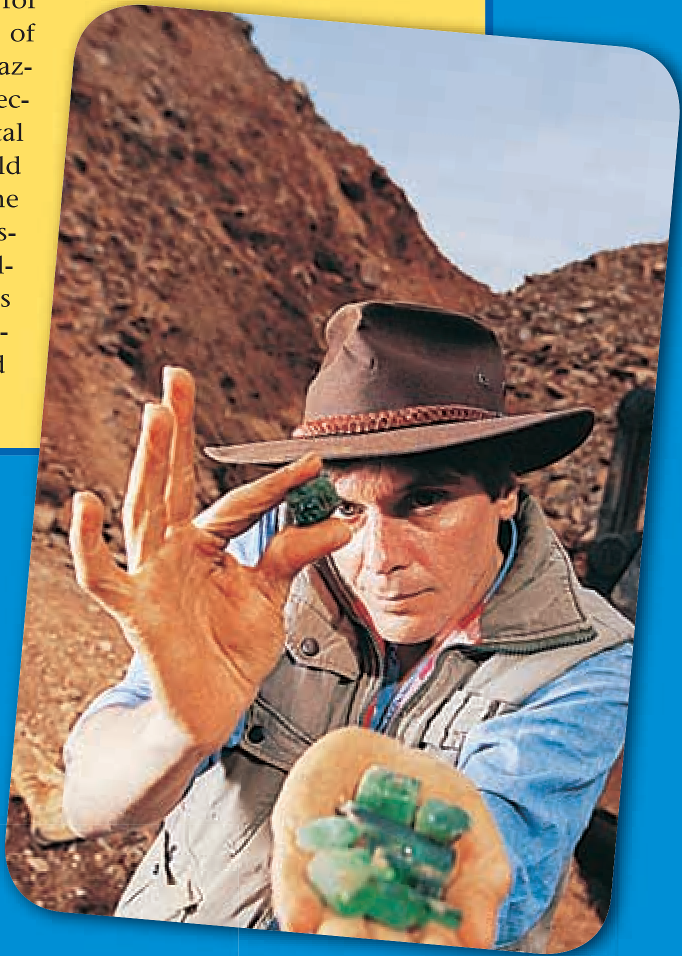
Copyright © by Holt, Rinehart and Winston. All rights reserved.

People in Science

Jamie Hill

The Emerald Man Jamie Hill was raised in the Brushy Mountains of North Carolina. While growing up, Hill gained firsthand knowledge of the fabulous green crystals that could be found in the mountains. These green crystals were emeralds. Emerald is the green variety of the silicate mineral beryl and is a valuable gemstone. In North Carolina, emerald crystals form in pockets, or openings, in rock known as *migmatite*.

Since 1985, Hill has been searching for emeralds in rock near the small town of Hiddenite, North Carolina. He has been amazingly successful. He has discovered some spectacular emerald crystals. The largest crystal weighs 1,862 carats and is the largest emerald discovered in North America. Estimates of the total value of the emeralds that Hill has discovered so far are well in the millions of dollars. Many newspaper and magazine articles have been written about Hill and his discoveries. Hill has also appeared on national and documentary TV shows.



Math ACTIVITY

An emerald discovered by Jamie Hill in 1999 was cut into a 7.85-carat stone that sold for \$64,000 per carat. What was the total value of the cut stone?

go.hrw.com

To learn more about these Science in Action topics, visit **go.hrw.com** and type in the keyword **HZ5MINF.**

Current Science

Check out Current Science® articles related to this chapter by visiting go.hrw.com. Just type in the keyword HZ5CS03.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

3

Rocks: Mineral Mixtures

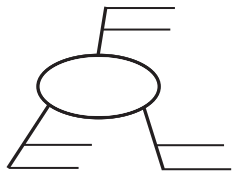
About the PHOTO

Irish legend claims that the mythical hero Finn MacCool built the Giant's Causeway, shown here. But this rock formation is the result of the cooling of huge amounts of molten rock. As the molten rock cooled, it formed tall pillars separated by cracks called *columnar joints*.

PRE-READING ACTIVITY

Graphic Organizer

Spider Map Before you read the chapter, create the graphic organizer entitled "Spider Map" described in the **Study Skills** section of the Appendix. Label the circle "Rock." Create a leg for each of the sections in this chapter. As you read the chapter, fill in the map with details about the material presented in each section of the chapter.



Copyright © by Holt, Rinehart and Winston. All rights reserved.

START-UP ACTIVITY

Classifying Objects

Scientists use the physical and chemical properties of rocks to classify rocks. Classifying objects such as rocks requires looking at many properties. Do this exercise for some classification practice.

Procedure

1. Your teacher will give you a **bag** containing **several objects.** Examine the objects, and note features such as size, color, shape, texture, smell, and any unique properties.
2. Develop three different ways to sort these objects.
3. Create a chart that organizes objects by properties.

Analysis

1. What properties did you use to sort the items?
2. Were there any objects that could fit into more than one group? How did you solve this problem?
3. Which properties might you use to classify rocks? Explain your answer.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 1

The Rock Cycle

You know that paper, plastic, and aluminum can be recycled. But did you know that the Earth also recycles? And one of the things that Earth recycles is rock.

Scientists define **rock** as a naturally occurring solid mixture of one or more minerals and organic matter. It may be hard to believe, but rocks are always changing. The continual process by which new rock forms from old rock material is called the **rock cycle.**

READING WARM-UP

Objectives

- List two economic uses of rocks found in North Carolina.
- Describe four processes that shape Earth's features.
- Describe how each type of rock changes into another type as it moves through the rock cycle.
- List two characteristics of rock that are used to help classify it.

Terms to Learn

rock cycle
rock
erosion
deposition
composition
texture

READING STRATEGY

Reading Organizer As you read this section, make a flowchart of the steps of the rock cycle.

The Value of Rock

Rock has also been used for centuries to make buildings, monuments, and roads. **Figure 1** shows how rock has been used as a construction material by both ancient and modern civilizations. Buildings have been made out of granite, limestone, marble, sandstone, slate, and other rocks. Modern buildings also contain concrete and plaster, in which rock is an important ingredient.

In North Carolina, rock is quarried to produce crushed stone, which is used to build dams, roads, and bridges. Split blocks of rock, called *dimension stone,* are quarried and used to construct buildings and monuments. Phosphate rock, which contains the element phosphorous, is mined and used to produce fertilizer, animal feed, and pesticides.

Reading Check **Name some types of rock that have been used to construct buildings.** (*See the Appendix for answers to Reading Checks.*)

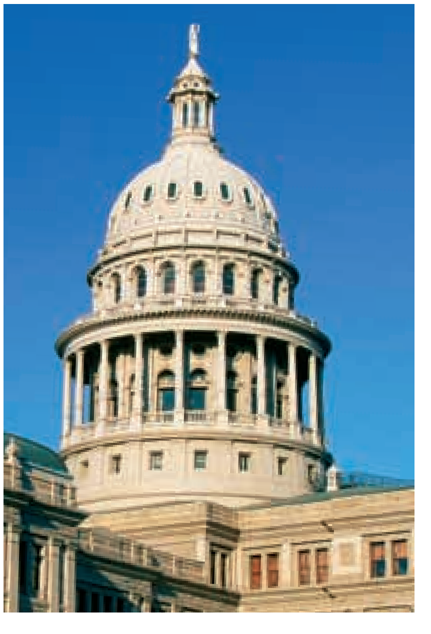


Figure 1 *The ancient Egyptians used a sedimentary rock called* limestone *to construct the pyramids at Giza (left). Granite, an igneous rock, was used to construct the Texas state capitol building in Austin (right).*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Processes That Shape the Earth

Certain geological processes make and destroy rock. These processes shape the features of our planet. These processes also influence the type of rock that is found in a certain area of Earth's surface.

rock a naturally occurring solid mixture of one or more minerals or organic matter

rock cycle the series of processes in which a rock forms, changes from one type to another, is destroyed, and forms again by geological processes

erosion the process by which wind, water, ice, or gravity transports soil and sediment from one location to another

deposition the process in which material is laid down

Weathering, Erosion, and Deposition

The process in which water, wind, ice, and heat break down rock is called *weathering*. Weathering is important because it breaks down rock into fragments. These rock and mineral fragments are the sediment of which much sedimentary rock is made.

The process by which sediment is removed from its source is called **erosion.** Water, wind, ice, and gravity can erode and move sediments and cause them to collect. **Figure 2** shows an example of the way land looks after weathering and erosion.

The process in which sediment moved by erosion is dropped and comes to rest is called **deposition.** Sediment is deposited in bodies of water and other low-lying areas. In those places, sediment may be pressed and cemented together by minerals dissolved in water to form sedimentary rock.

Heat and Pressure

Sedimentary rock made of sediment can also form when buried sediment is squeezed by the weight of overlying layers of sediment. If the temperature and pressure are high enough at the bottom of the sediment, the rock can change into metamorphic rock. In some cases, the rock gets hot enough to melt. This melting creates the magma that eventually cools to form igneous rock.

How the Cycle Continues

Buried rock is exposed at the Earth's surface by a combination of uplift and erosion. *Uplift* is movement within the Earth that causes rocks inside the Earth to be moved to the Earth's surface. When uplifted rock reaches the Earth's surface, weathering, erosion, and deposition begin.

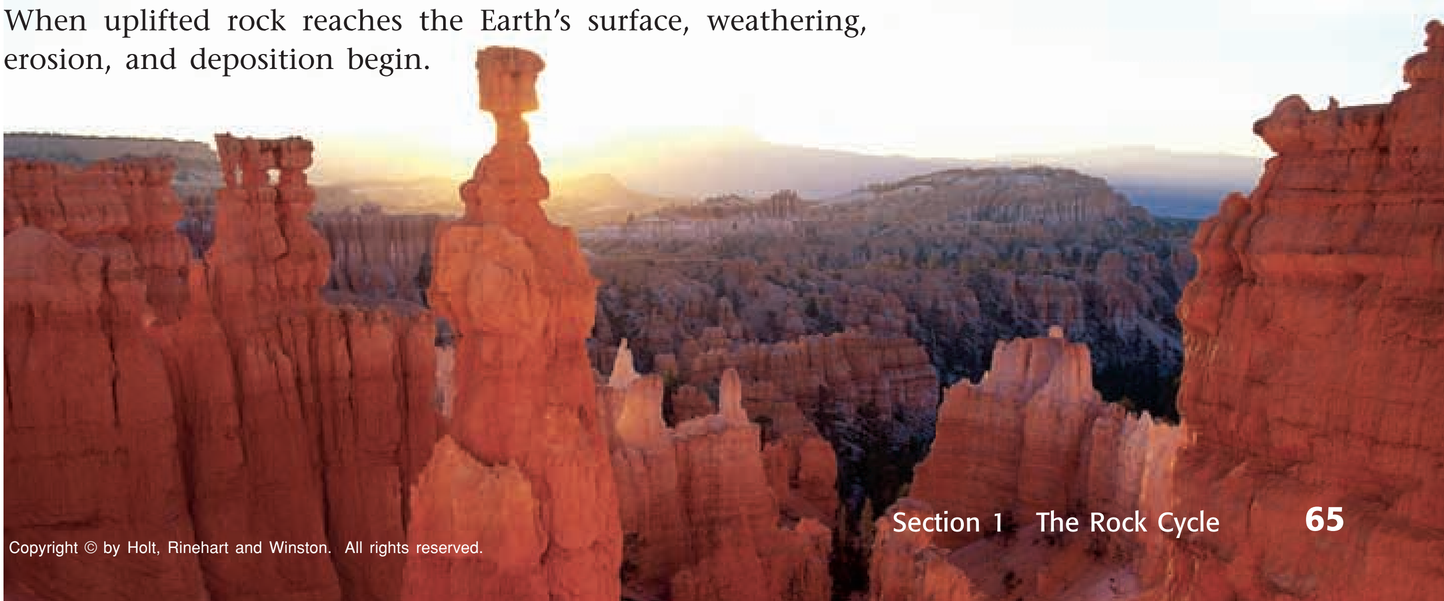
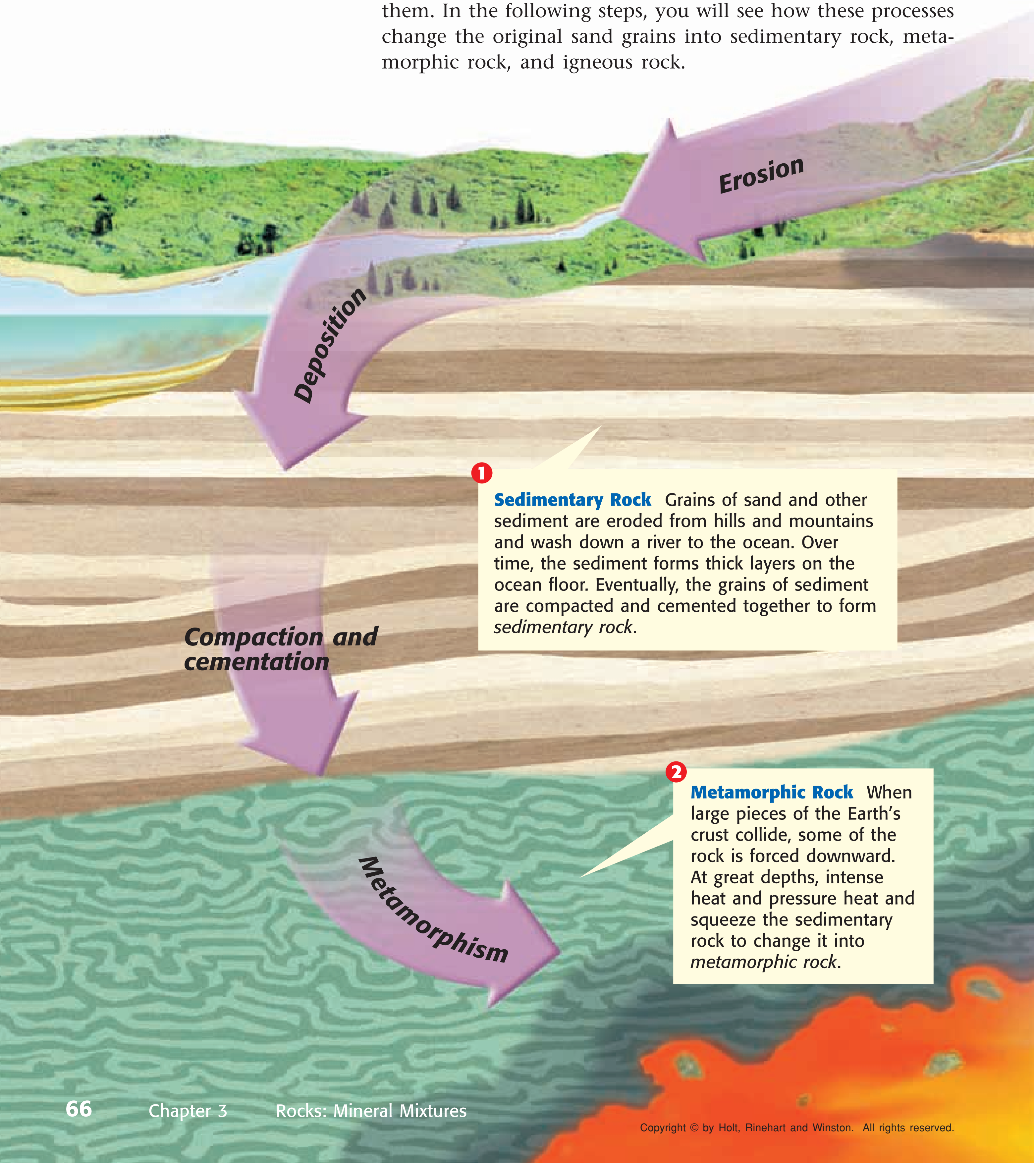


Figure 2 *Bryce Canyon, in Utah, is an excellent example of how the processes of weathering and erosion shape the face of our planet.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Illustrating the Rock Cycle

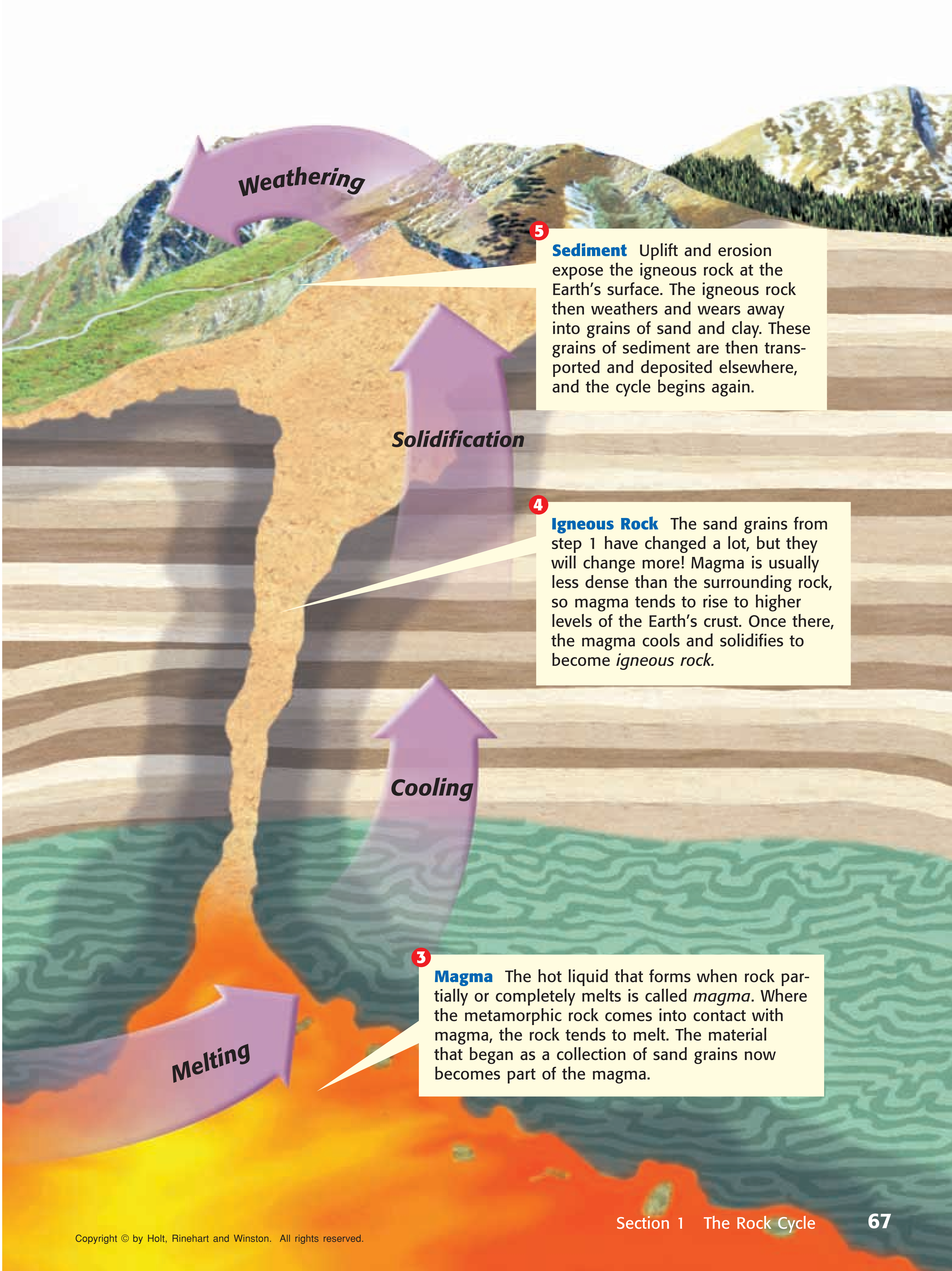
You have learned about various geological processes, such as weathering, erosion, heat, and pressure, that create and destroy rock. The diagram on these two pages illustrates one way that sand grains can change as different geological processes act on them. In the following steps, you will see how these processes change the original sand grains into sedimentary rock, metamorphic rock, and igneous rock.



1 **Sedimentary Rock** Grains of sand and other sediment are eroded from hills and mountains and wash down a river to the ocean. Over time, the sediment forms thick layers on the ocean floor. Eventually, the grains of sediment are compacted and cemented together to form *sedimentary rock*.

2 **Metamorphic Rock** When large pieces of the Earth's crust collide, some of the rock is forced downward. At great depths, intense heat and pressure heat and squeeze the sedimentary rock to change it into *metamorphic rock*.

Copyright © by Holt, Rinehart and Winston. All rights reserved.



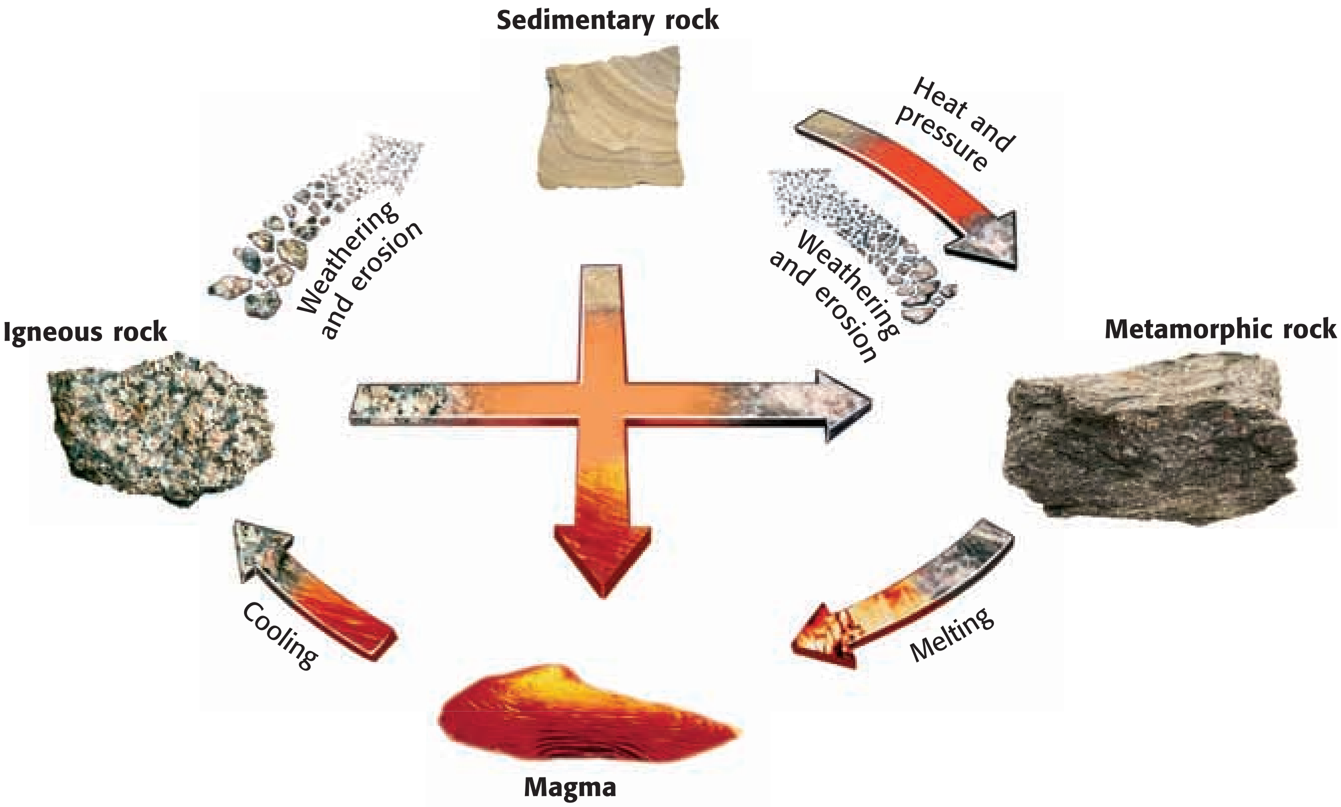
5 Sediment Uplift and erosion expose the igneous rock at the Earth's surface. The igneous rock then weathers and wears away into grains of sand and clay. These grains of sediment are then transported and deposited elsewhere, and the cycle begins again.

4 Igneous Rock The sand grains from step 1 have changed a lot, but they will change more! Magma is usually less dense than the surrounding rock, so magma tends to rise to higher levels of the Earth's crust. Once there, the magma cools and solidifies to become *igneous rock.*

3 Magma The hot liquid that forms when rock partially or completely melts is called *magma*. Where the metamorphic rock comes into contact with magma, the rock tends to melt. The material that began as a collection of sand grains now becomes part of the magma.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 3 The Rock Cycle



Round and Round It Goes

You have seen how different geological processes can change rock. Each rock type can change into one of the three types of rock. For example, igneous rock can change into sedimentary rock, metamorphic rock, or even back into igneous rock. This cycle, in which rock is changed by geological processes into different types of rock, is known as the rock cycle.

Rocks may follow various pathways in the rock cycle. As one rock type is changed to another type, several variables, including time, heat, pressure, weathering, and erosion may alter a rock's identity. The location of a rock determines which natural forces will have the biggest impact on the process of change. For example, rock at the Earth's surface is primarily affected by forces of weathering and erosion, whereas deep inside the Earth, rocks change because of extreme heat and pressure. **Figure 3** shows the different ways rock may change when it goes through the rock cycle and the different forces that affect rock during the cycle.

Reading Check **What processes change rock deep within the Earth?**

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Rock Classification

You have already learned that scientists divide all rock into three main classes based on how the rock formed: igneous, sedimentary, and metamorphic. But did you know that each class of rock can be divided further? These divisions are also based on differences in the way rocks form. For example, all igneous rock forms when magma cools and solidifies. But some igneous rocks form when magma cools *on* the Earth's surface, and others form when magma cools deep *beneath* the surface. Therefore, igneous rock can be divided again based on how and where it forms. Sedimentary and metamorphic rocks are also divided into groups. How do scientists know how to classify rocks? They study rocks in detail using two important criteria—composition and texture.

MATH PRACTICE

What's in It?

Assume that a granite sample you are studying is made of 30% quartz and 55% feldspar by volume. The rest is made of biotite mica. What percentage of the sample is biotite mica?

Composition

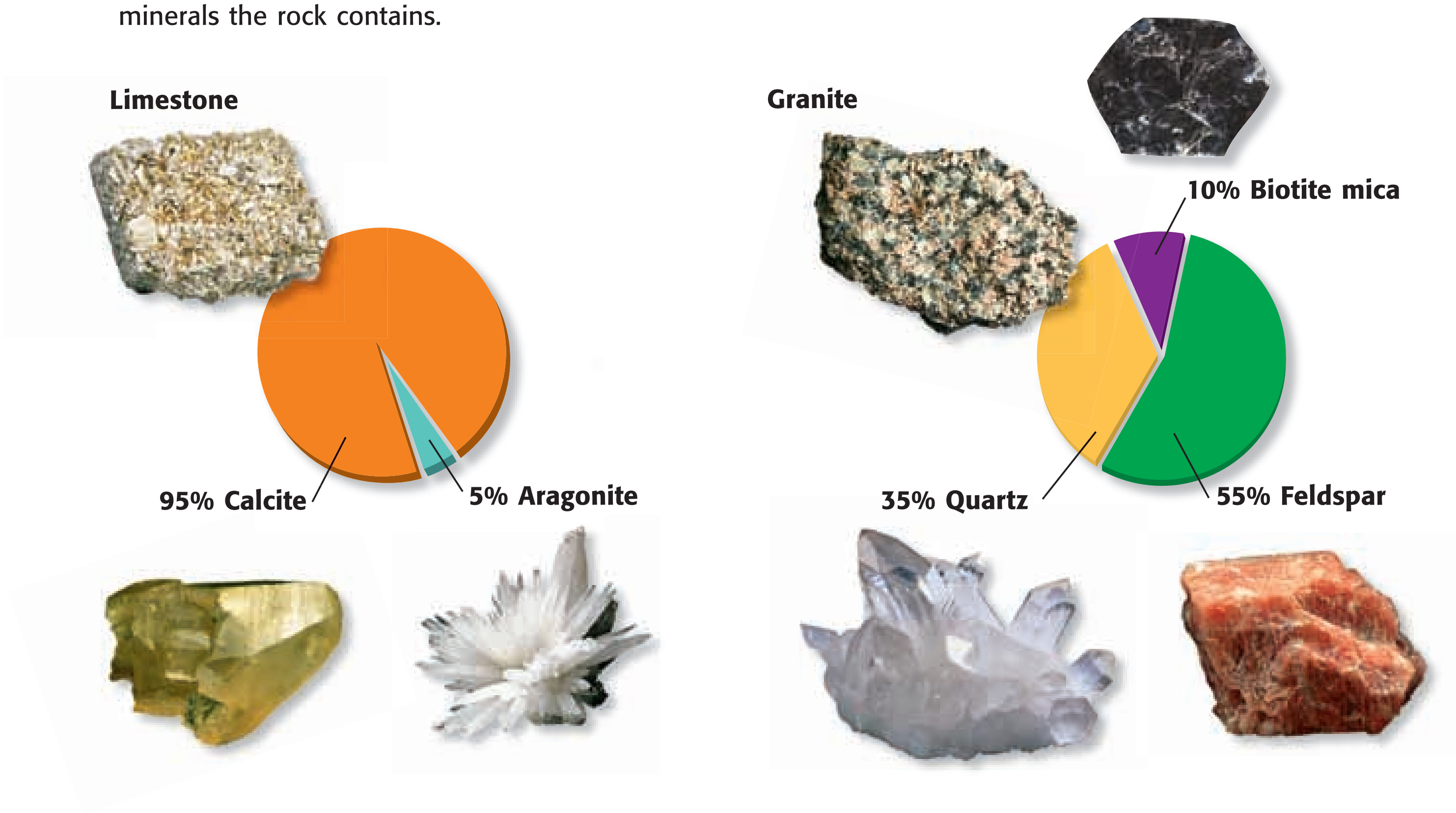
The minerals a rock contains determine the **composition** of that rock, as shown in **Figure 4.** For example, a rock made of mostly the mineral quartz will have a composition very similar to that of quartz. But a rock made of 50% quartz and 50% feldspar will have a very different composition than quartz does.

composition the chemical makeup of a rock; describes either the minerals or other materials in the rock

Reading Check **What determines a rock's composition?**

Figure 4 **Two Examples of Rock Composition**

The composition of a rock depends on the minerals the rock contains.



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 5 **Three Examples of Sedimentary Rock Texture**

Fine-grained: Siltstone

Medium-grained: Sandstone

Coarse-grained: Conglomerate

Texture

texture the quality of a rock that is based on the sizes, shapes, and positions of the rock's grains

The size, shape, and positions of the grains that make up a rock determine a rock's **texture.** Sedimentary rock can have a fine-grained, medium-grained, or coarse-grained texture, depending on the size of the grains that make up the rock. Three samples of textures are shown in **Figure 5.** The texture of igneous rock can be fine-grained or coarse-grained, depending on how much time magma has to cool. Based on the degree of temperature and pressure a rock is exposed to, metamorphic rock can also have a fine-grained or coarse-grained texture.

The texture of a rock can provide clues as to how and where the rock formed. Look at the rocks shown in **Figure 6.** The rocks look different because they formed in very different ways. The texture of a rock can reveal the process that formed it.

✓ *Reading Check* **Give three examples of sedimentary rock textures.**

Figure 6 **Texture and Rock Formation**

Basalt, a fine-grained igneous rock, forms when lava that erupts onto Earth's surface cools rapidly.

Sandstone, a medium-grained sedimentary rock, forms when sand grains deposited in dunes, on beaches, or on the ocean floor are buried and cemented.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION
Review

Summary

- Rock has been an important natural resource for as long as humans have existed. Early humans used rock to make tools. Ancient and modern civilizations have used rock as a construction material.
- Weathering, erosion, deposition, and uplift are all processes that shape the surface features of the Earth.
- The rock cycle is the continual process by which new rock forms from old rock material.
- The sequence of events in the rock cycle depends on processes, such as weathering, erosion, deposition, pressure, and heat, that change the rock material.
- Composition and texture are two characteristics that scientists use to classify rocks.
- The composition of a rock is determined by the minerals that make up the rock.
- The texture of a rock is determined by the size, shape, and positions of the grains that make up the rock.

Using Key Terms

Complete each of the following sentences by choosing the correct term from the word bank.

rock	composition
rock cycle	texture

1. The minerals that a rock is made of determine the ___ of that rock.
2. ___ is a naturally occurring, solid mixture of crystals of one or more minerals.

Understanding Key Ideas

3. Sediments are transported or moved from their original source by a process called
   a. deposition.
   b. erosion.
   c. uplift.
   d. weathering.
4. List two economic uses of rocks found in North Carolina.
5. Name four processes that change rock inside the Earth.
6. Describe four processes that shape Earth's surface.
7. Give an example of how texture can provide clues as to how and where a rock formed.

Critical Thinking

8. **Making Comparisons** Explain the difference between texture and composition.
9. **Analyzing Processes** Explain how rock is continually recycled in the rock cycle.

Interpreting Graphics

10. Look at the table below. Sandstone is a type of sedimentary rock. If you had a sample of sandstone that had an average particle size of 2 mm, what texture would your sandstone have?

Classification of Clastic Sedimentary Rocks

Texture	Particle size
coarse grained	> 2 mm
medium grained	0.06 to 2 mm
fine grained	< 0.06 mm

SCILINKS®
NSTA
Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Composition of Rock
SciLinks code: HSM0327

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 2

Igneous Rock

Where do igneous rocks come from? Here's a hint: The word igneous *comes from a Latin word that means "fire."*

READING WARM-UP

Objectives

- Describe three ways that igneous rock forms.
- Explain how the cooling rate of magma affects the texture of igneous rock.
- Distinguish between igneous rock that cools within Earth's crust and igneous rock that cools at Earth's surface.

Terms to Learn

intrusive igneous rock
extrusive igneous rock

READING STRATEGY

Reading Organizer As you read this section, make a table comparing intrusive rock and extrusive rock.

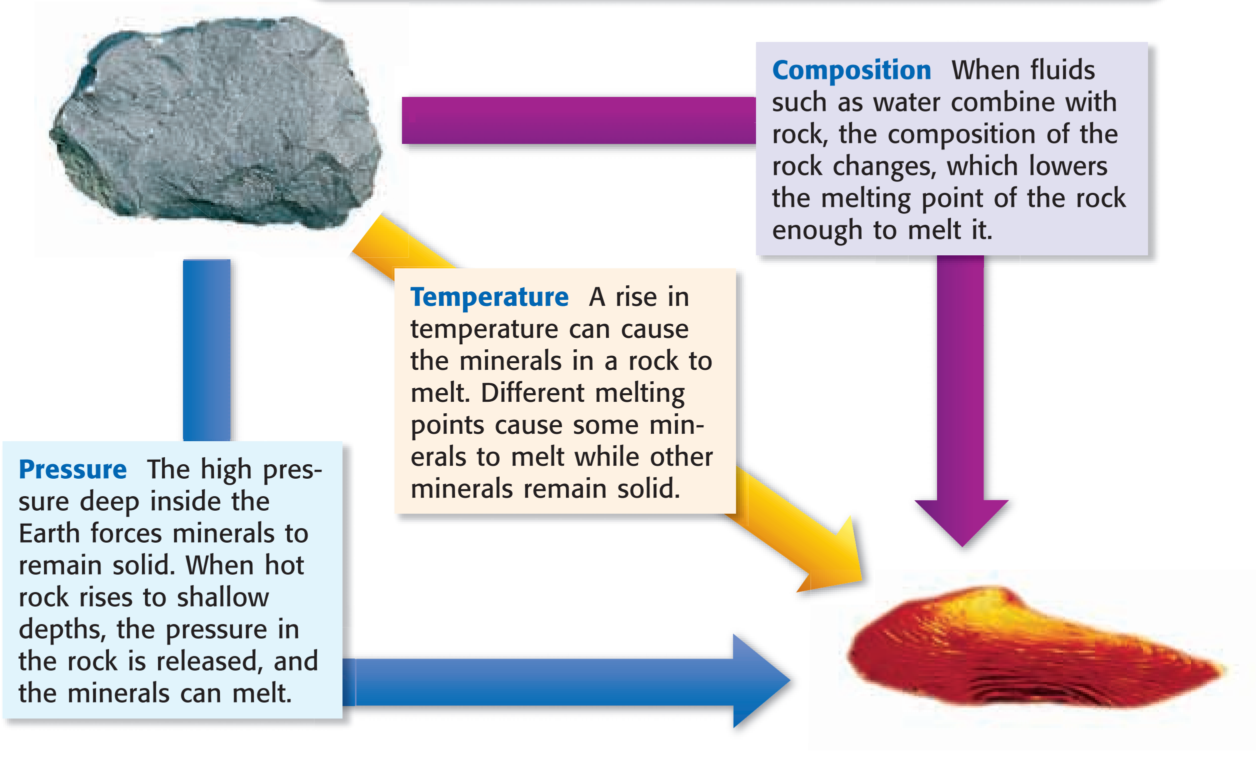
Igneous rock forms when hot, liquid rock, or *magma,* cools and solidifies. The type of igneous rock that forms depends on the composition of the magma and the amount of time it takes the magma to cool.

Origins of Igneous Rock

Igneous rock begins as magma. As shown in **Figure 1,** there are three ways magma can form: when rock is heated, when pressure is released, or when rock changes composition.

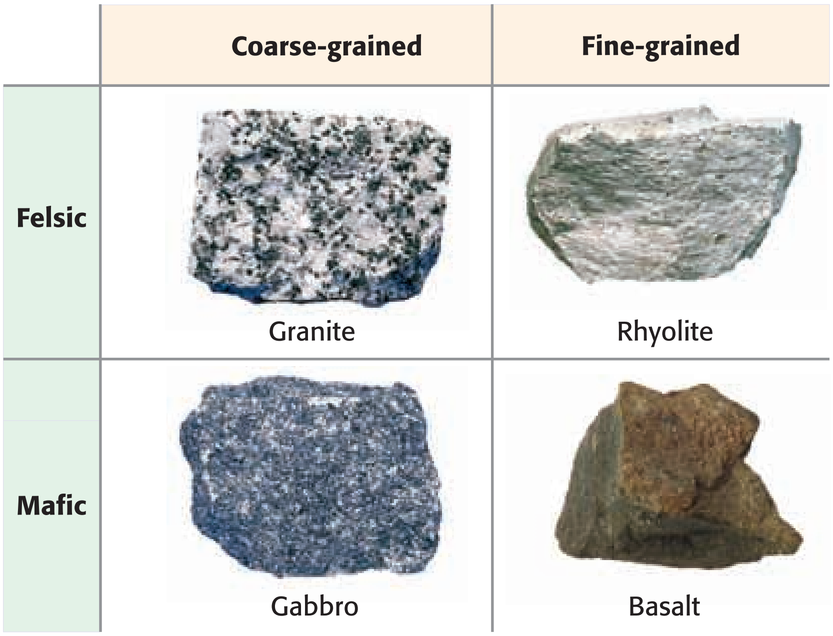
When magma cools enough, it solidifies to form igneous rock. Magma solidifies in much the same way that water freezes. But there are also differences between the way magma freezes and the way water freezes. One main difference is that water freezes at 0°C. Magma freezes between 700°C and 1,250°C. Also, liquid magma is a complex mixture containing many melted minerals. Because these minerals have different melting points, some minerals in the magma will freeze or become solid before other minerals do.

Figure 1 **The Formation of Magma**



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 2 **Igneous Rock Texture**



Composition and Texture of Igneous Rock

Look at the rocks in **Figure 2.** All of the rocks are igneous rocks even though they look different from one another. These rocks differ from one another in what they are made of and how fast they cooled.

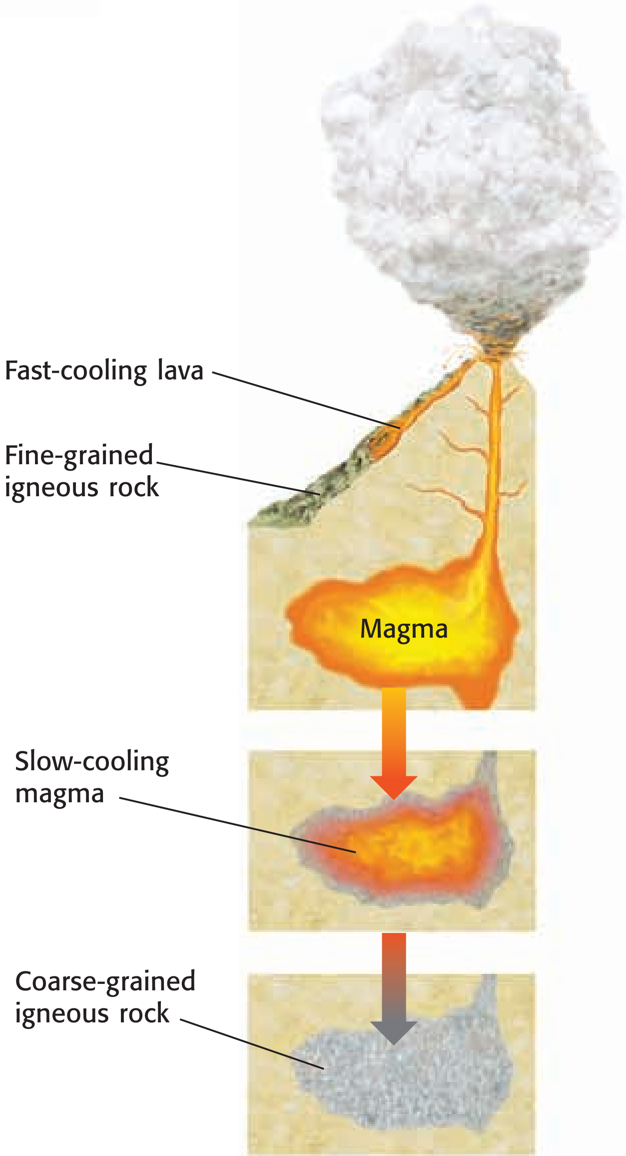
The light-colored rocks are less dense than the dark-colored rocks are. The light-colored rocks are rich in elements such as aluminum, potassium, silicon, and sodium. These rocks are called *felsic rocks*. The dark-colored rocks, called *mafic rocks,* are rich in calcium, iron, and magnesium, and poor in silicon.

Figure 3 shows what happens to magma when it cools at different rates. The longer it takes for the magma or lava to cool, the more time mineral crystals have to grow. The more time the crystals have to grow, the larger the crystals are and the coarser the texture of the resulting igneous rock is.

In contrast, the less time magma takes to cool, the less time crystals have to grow. Therefore, the rock that is formed will be fine grained. Fine-grained igneous rock contains very small crystals, or if the cooling is very rapid, it contains no crystals.

Reading Check **Explain the difference between felsic rock and mafic rock.** (*See the Appendix for answers to Reading Checks.*)

Figure 3 *The amount of time it takes for magma or lava to cool determines the texture of igneous rock.*



Copyright © by Holt, Rinehart and Winston. All rights reserved.

INTERNET ACTIVITY

For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HZ5RCKW.**

Igneous Rock Formations

Igneous rock formations are located above and below the surface of the Earth. You may be familiar with igneous rock formations that were caused by lava cooling on the Earth's surface, such as volcanoes. But not all magma reaches the surface. Some magma cools and solidifies deep within the Earth's crust.

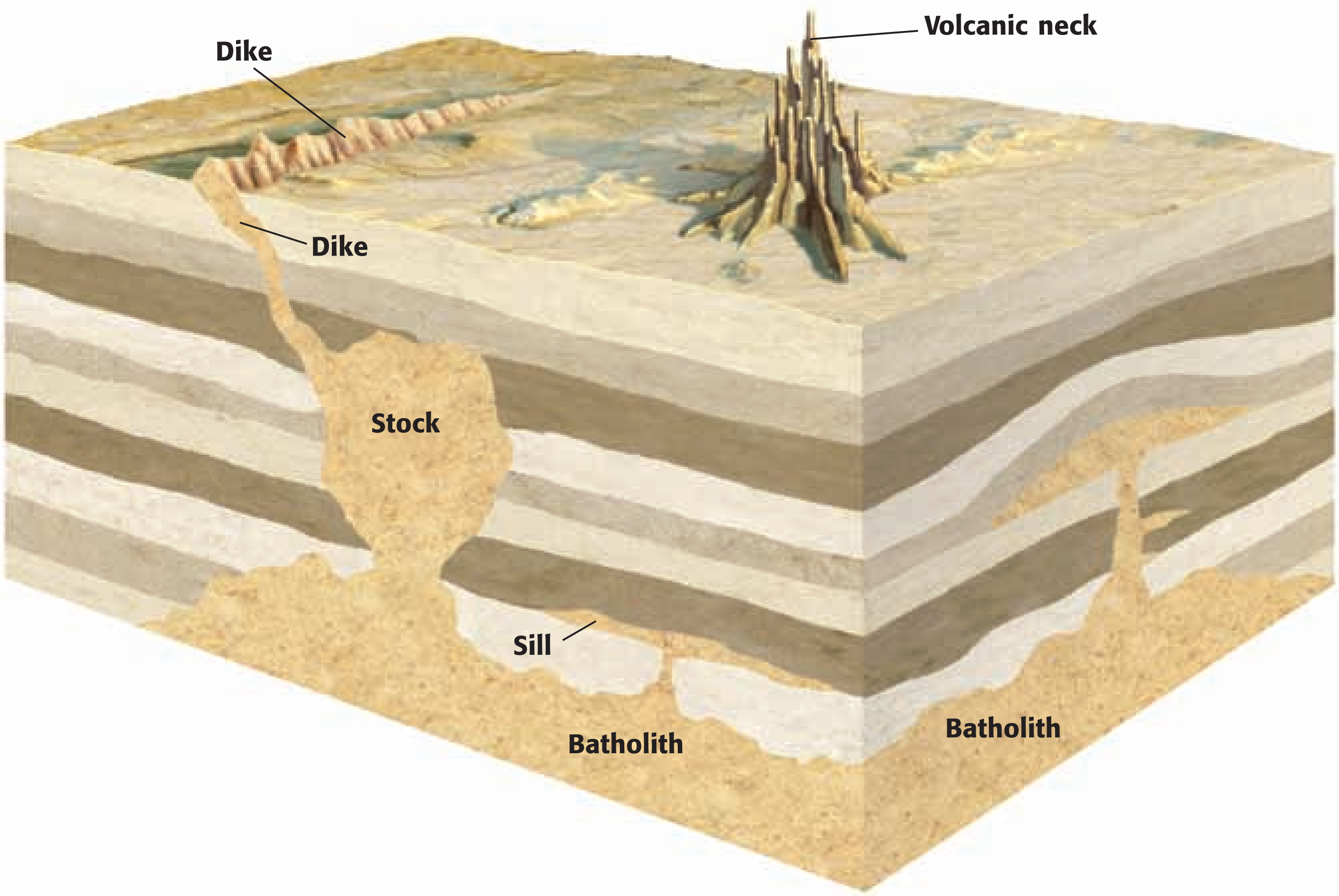
Intrusive Igneous Rock

intrusive igneous rock rock formed from the cooling and solidification of magma beneath the Earth's surface

When magma *intrudes*, or pushes, into surrounding rock below the Earth's surface and cools, the rock that forms is called **intrusive igneous rock.** Intrusive igneous rock usually has a coarse-grained texture because it is well insulated by surrounding rock and cools very slowly. The minerals that form are large, visible crystals.

Masses of intrusive igneous rock are named for their size and shape. Common intrusive shapes are shown in **Figure 4.** *Plutons* are large, irregular-shaped intrusive bodies. The largest of all igneous intrusions are *batholiths*. *Stocks* are intrusive bodies that are exposed over smaller areas than batholiths. Sheetlike intrusions that cut across previous rock units are called *dikes*, whereas *sills* are sheetlike intrusions that are oriented parallel to previous rock units.

Figure 4 *Igneous intrusive bodies have different shapes and sizes.*



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Extrusive Igneous Rock

Igneous rock that forms from magma that erupts, or extrudes, onto the Earth's surface is called **extrusive igneous rock.** Extrusive rock is common around volcanoes. It cools quickly on the surface and contains very small crystals or no crystals.

When lava erupts from a volcano, a *lava flow* forms. **Figure 5** shows an active lava flow. Lava does not always flow from volcanoes. Sometimes lava erupts and flows from long cracks in the Earth's crust called *fissures*. Lava flows from fissures on the ocean floor at places where tension is causing the ocean floor to be pulled apart. This lava cools to form new ocean floor. When a large amount of lava flows out of fissures onto land, the lava can cover a large area and form a plain called a *lava plateau*. Pre-existing landforms are often buried by these lava flows.

Reading Check How does new ocean floor form?

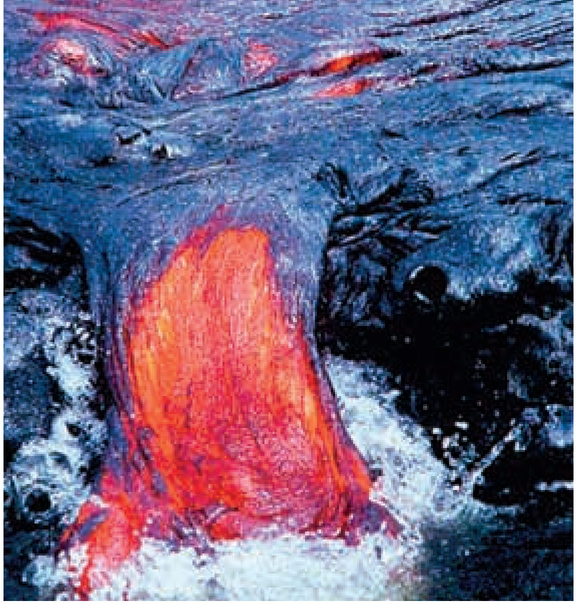


Figure 5 *An active lava flow is shown in this photo. When exposed to Earth's surface conditions, lava quickly cools and solidifies to form a fine-grained igneous rock.*

extrusive igneous rock rock that forms as a result of volcanic activity at or near the Earth's surface

SECTION Review

Summary

- Igneous rock forms when magma cools and hardens.
- The texture of igneous rock is determined by the rate at which the rock cools.
- Igneous rock that solidifies at Earth's surface is extrusive. Igneous rock that solidifies within Earth's surface is intrusive.
- Shapes of common igneous intrusive bodies include batholiths, stocks, sills, and dikes.

Using Key Terms

1. In your own words, write a definition for each of the following terms: *intrusive igneous rock* and *extrusive igneous rock*.

Understanding Key Ideas

2. ___ is an example of a coarse-grained, felsic, igneous rock.
   a. Basalt
   b. Gabbro
   c. Granite
   d. Rhyolite
3. Explain three ways in which magma can form.
4. What determines the texture of igneous rocks?

Math Skills

5. The summit of a granite batholith has an elevation of 1,825 ft. What is the height of the batholith in meters?

Critical Thinking

6. **Making Comparisons** Dikes and sills are both types of igneous intrusive bodies. What is the difference between a dike and a sill?
7. **Predicting Consequences** An igneous rock forms from slow-cooling magma deep beneath the surface of the Earth. What type of texture is this rock most likely to have? Explain.

SCILINKS
NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Igneous Rock
SciLinks code: HSM0783

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 3

Sedimentary Rock

Have you ever tried to build a sand castle at the beach? Did you ever wonder where the sand came from?

Sand is a product of weathering, which breaks rock into pieces. Over time, sand grains may be compacted, or compressed, and then cemented together to form a rock called *sandstone*. Sandstone is just one of many types of sedimentary rock.

Origins of Sedimentary Rock

Wind, water, ice, sunlight, and gravity all cause rock to physically weather into fragments. Through the process of erosion, these rock and mineral fragments, called *sediment*, are moved from one place to another. Eventually, the sediment is deposited in layers. As new layers of sediment are deposited, they cover older layers. Older layers become compacted. Dissolved minerals, such as calcite and quartz, separate from water that passes through the sediment to form a natural cement that binds the rock and mineral fragments together into sedimentary rock.

Sedimentary rock forms at or near the Earth's surface. It forms without the heat and pressure that are involved in the formation of igneous and metamorphic rocks.

The most noticeable feature of sedimentary rock is its layers, or **strata.** A single, horizontal layer of rock is sometimes visible for many miles. Road cuts are good places to observe strata. **Figure 1** shows the spectacular views that sedimentary rock formations carved by erosion can provide.

READING WARM-UP

Objectives

- Describe the origin of sedimentary rock.
- Describe the three main categories of sedimentary rock.
- Describe three types of sedimentary structures.

Terms to Learn

strata
stratification

READING STRATEGY

Reading Organizer As you read this section, create an outline of this section. Use the headings from the section in your outline.

Figure 1 *The red sandstone "monuments" for which Monument Valley in Arizona has been named are the products of millions of years of erosion.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 2 **Classification of Clastic Sedimentary Rock**

Composition of Sedimentary Rock

Sedimentary rock is classified by the way it forms. *Clastic sedimentary rock* forms when rock or mineral fragments, called *clasts,* are cemented together. *Chemical sedimentary rock* forms when minerals crystallize out of a solution, such as sea water, to become rock. *Organic sedimentary rock* forms from the remains of once-living plants and animals.

strata layers of rock (singular, *stratum*)

Clastic Sedimentary Rock

Clastic sedimentary rock is made of fragments of rocks cemented together by a mineral such as calcite or quartz. **Figure 2** shows how clastic sedimentary rock is classified according to the size of the fragments from which the rock is made. Clastic sedimentary rocks can have coarse-grained, medium-grained, or fine-grained textures.

Chemical Sedimentary Rock

Chemical sedimentary rock forms from solutions of dissolved minerals and water. As rainwater slowly makes its way to the ocean, it dissolves some of the rock material it passes through. Some of this dissolved material eventually crystallizes and forms the minerals that make up chemical sedimentary rock. Halite, one type of chemical sedimentary rock, is made of sodium chloride, NaCl, or table salt. Halite forms when sodium ions and chlorine ions in shallow bodies of water become so concentrated that halite crystallizes from solution.

Reading Check **How does a chemical sedimentary rock such as halite form?** (*See the Appendix for answers to Reading Checks.*)

CONNECTION TO Language Arts

WRITING SKILL **Salty Expressions** The word salt is used in many expressions in the English language. Some common examples include "the salt of the earth," "taken with a grain of salt," not worth his salt," "the salt of truth," "rubbing salt into a wound," and "old salt." Use the Internet or another source to research one these expressions. In your research, attempt to find the origin of the expression. Write a short paragraph that summarizes what you found.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Organic Sedimentary Rock

Figure 3 *Ocean animals called* coral *create huge deposits of limestone. As they die, their skeletons collect on the ocean floor.*

Most limestone forms from the remains, or *fossils*, of animals that once lived in the ocean. For example, some limestone is made of the skeletons of tiny organisms called *coral*. Coral are very small, but they live in huge colonies called *reefs*, shown in **Figure 3.** Over time, the skeletons of these sea animals, which are made of calcium carbonate, collect on the ocean floor. These animal remains eventually become cemented together to form *fossiliferous limestone* (FAH suhl IF uhr uhs LIEM STOHN).

Corals are not the only animals whose remains are found in fossiliferous limestone. The shells of mollusks, such as clams and oysters, commonly form fossiliferous limestone. An example of fossiliferous limestone that contains mollusks is shown in **Figure 4.**

Another type of organic sedimentary rock is *coal*. Coal forms underground when partially decomposed plant material is buried beneath sediment and is changed into coal by increasing heat and pressure. This process occurs over millions of years.

Figure 4 The Formation of Organic Sedimentary Rock

Marine organisms, such as brachiopods, get the calcium carbonate for their shells from ocean water. When these organisms die, their shells collect on the ocean floor and eventually form fossiliferous limestone (inset). Over time, huge rock formations that contain the remains of large numbers of organisms, such as brachiopods, form.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Sedimentary Rock Structures

Many features can tell you about the way sedimentary rock formed. The most important feature of sedimentary rock is stratification. **Stratification** is the process in which sedimentary rocks are arranged in layers. Strata differ from one another depending on the kind, size, and color of their sediment.

Sedimentary rocks sometimes record the motion of wind and water waves on lakes, oceans, rivers, and sand dunes in features called *ripple marks*, as shown in **Figure 5.** Structures called *mud cracks* form when fine-grained sediments at the bottom of a shallow body of water are exposed to the air and dry out. Mud cracks indicate the location of an ancient lake, stream, or ocean shoreline. Even raindrop impressions can be preserved in fine-grained sediments, as small pits with raised rims.

Reading Check **What are ripple marks?**

Figure 5 *These ripple marks were made by flowing water and were preserved when the sediments became sedimentary rock. Ripple marks can also form from the action of wind.*

stratification the process in which sedimentary rocks are arranged in layers

SECTION Review

Summary

- Sedimentary rock forms at or near the Earth's surface.
- Clastic sedimentary rock forms when rock or mineral fragments are cemented together.
- Chemical sedimentary rock forms from solutions of dissolved minerals and water.
- Organic limestone forms from the remains of plants and animals.
- Sedimentary structures include ripple marks, mud cracks, and raindrop impressions.

Using Key Terms

1. In your own words, write a definition for each of the following terms: *strata* and *stratification.*

Understanding Key Ideas

2. Which of the following is an organic sedimentary rock?
   a. chemical limestone
   b. shale
   c. fossiliferous limestone
   d. conglomerate
3. Explain the process by which clastic sedimentary rock forms.
4. Describe the three main categories of sedimentary rock.

Math Skills

5. A layer of a sedimentary rock is 2 m thick. How many years did it take for this layer to form if an average of 4 mm of sediment accumulated per year?

Critical Thinking

6. **Identifying Relationships** Rocks are classified based on texture and composition. Which of these two properties would be more important for classifying clastic sedimentary rock?
7. **Analyzing Processes** Why do you think raindrop impressions are more likely to be preserved in fine-grained sedimentary rock rather than in coarse-grained sedimentary rock?

SCILINKS. NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Sedimentary Rock
SciLinks code: HSM1365

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 4

Metamorphic Rock

Have you ever watched a caterpillar change into a butterfly? Some caterpillars go through a biological process called metamorphosis in which they completely change their shape.

Rocks can also go through a process called *metamorphism*. The word *metamorphism* comes from the Greek words *meta,* which means "changed," and *morphos,* which means "shape." Metamorphic rocks are rocks in which the structure, texture, or composition of the rock have changed. All three types of rock can be changed by heat, pressure, or a combination of both.

READING WARM-UP

Objectives

- Describe two ways a rock can undergo metamorphism.
- Explain how the mineral composition of rocks changes as the rocks undergo metamorphism.
- Describe the difference between foliated and nonfoliated metamorphic rock.
- Explain how metamorphic rock structures are related to deformation.

Terms to Learn

foliated
nonfoliated

READING STRATEGY

Discussion Read this section silently. Write down questions that you have about this section. Discuss your questions in a small group.

Origins of Metamorphic Rock

The texture or mineral composition of a rock can change when its surroundings change. If the temperature or pressure of the new environment is different from the one in which the rock formed, the rock will undergo metamorphism.

The temperature at which most metamorphism occurs ranges from 50°C to 1,000°C. However, the metamorphism of some rocks takes place at temperatures above 1,000°C. It seems that at these temperatures the rock would melt, but this is not true of metamorphic rock. It is the depth and pressure at which metamorphic rocks form that allows the rock to heat to this temperature and maintain its solid nature. Most metamorphic change takes place at depths greater than 2 km. But at depths greater than 16 km, the pressure can be 4,000 times greater than the pressure of the atmosphere at Earth's surface.

Large movements within the crust of the Earth cause additional pressure to be exerted on a rock during metamorphism. This pressure can cause the mineral grains in rock to align themselves in certain directions. The alignment of mineral grains into parallel bands is shown in the metamorphic rock in **Figure 1.**

Figure 1 *This metamorphic rock is an example of how mineral grains were aligned into distinct bands when the rock underwent metamorphism.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

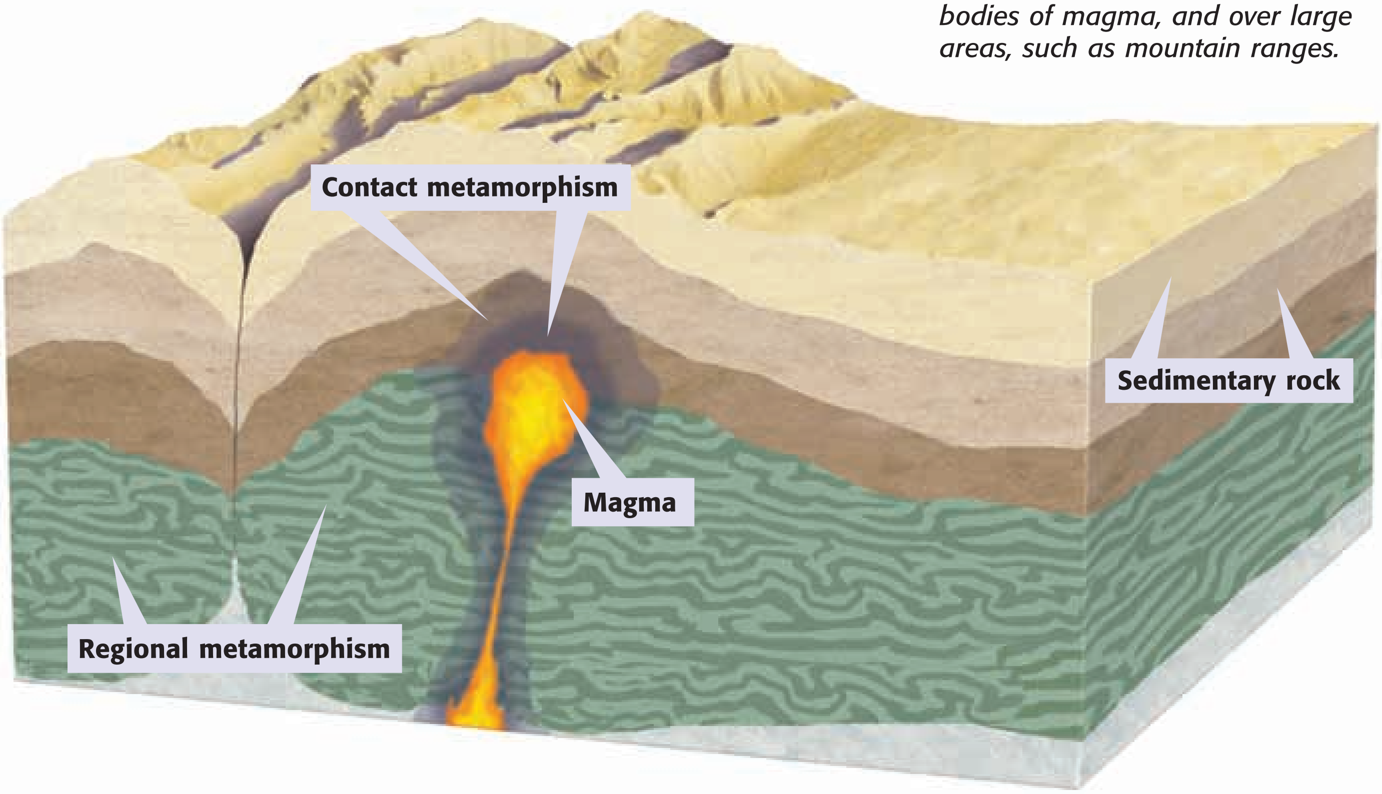


Figure 2 *Metamorphism occurs over small areas, such as next to bodies of magma, and over large areas, such as mountain ranges.*

Contact Metamorphism

One way rock can undergo metamorphism is by being heated by nearby magma. When magma moves through the crust, the magma heats the surrounding rock and changes it. Some minerals in the surrounding rock are changed into other minerals by this increase in temperature. The greatest change takes place where magma comes into direct contact with the surrounding rock. The effect of heat on rock gradually decreases as the rock's distance from the magma increases and as temperature decreases. *Contact metamorphism* occurs near igneous intrusions, as shown in **Figure 2.**

Regional Metamorphism

When pressure builds up in rock that is buried deep below other rock formations or when large pieces of the Earth's crust collide with each other, *regional metamorphism* occurs. The increased pressure and temperature causes rock to become deformed and chemically changed. Unlike contact metamorphism, which happens near bodies of magma, regional metamorphism occurs over thousands of cubic kilometers deep within Earth's crust. Rocks that have undergone regional metamorphism are found beneath most continental rock formations.

Reading Check **Explain how and where regional metamorphism takes place.** (*See the Appendix for answers to Reading Checks.*)

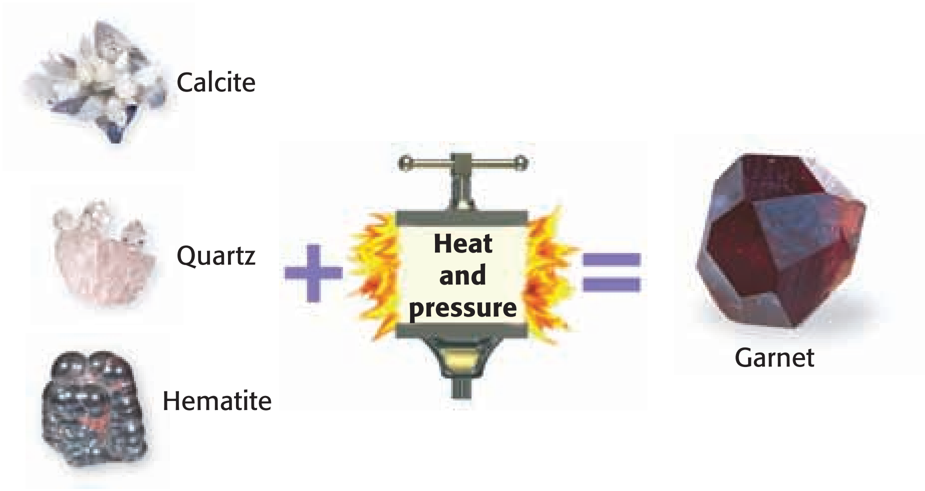
Quick Lab

Stretching Out

1. Sketch the crystals in granite rock on a **piece of paper** with a **black-ink pen.** Be sure to include the outline of the rock, and fill it in with different crystal shapes.
2. Flatten some **plastic play putty** over your drawing, and slowly peel it off.
3. After making sure that the outline of your granite has been transferred to the putty, squeeze and stretch the putty. What happened to the crystals in the granite? What happened to the granite?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 3 *The minerals calcite, quartz, and hematite combine and recrystallize to form the metamorphic mineral garnet.*



SCHOOL to HOME

Making a Rock Collection

With a parent, try to collect a sample of each class of rock described in this chapter. You may wish to collect rocks from road cuts or simply collect pebbles from your garden or driveway. Try to collect samples that show the composition and texture of each rock. Classify the rocks in your collection, and bring it to class. With other members of the class, discuss your rock samples and see if they are accurately identified.

ACTIVITY

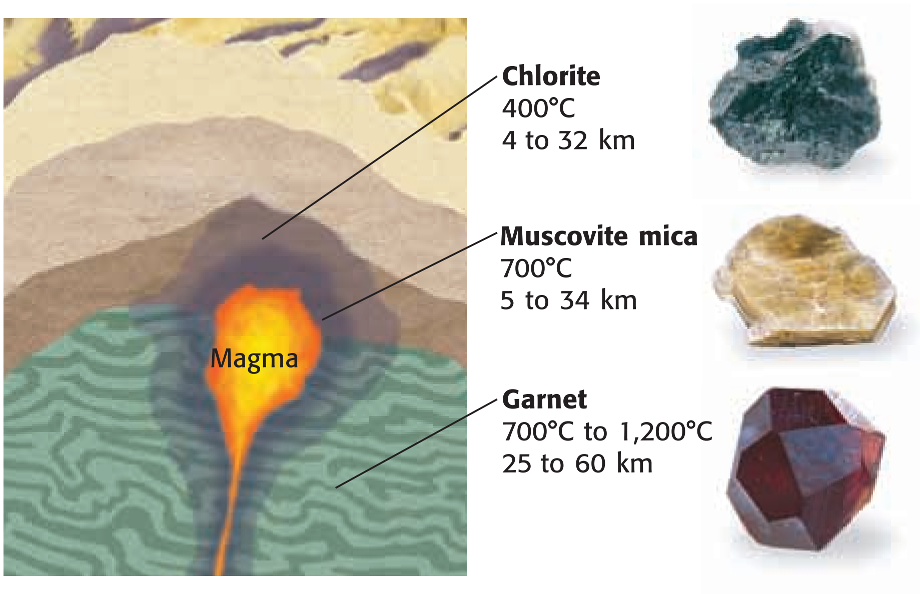
Composition of Metamorphic Rock

Metamorphism occurs when temperature and pressure inside the Earth's crust change. Minerals that were present in the rock when it formed may not be stable in the new temperature and pressure conditions. The original minerals change into minerals that are more stable in these new conditions. Look at **Figure 3** to see an example of how this change happens.

Many of these new minerals form only in metamorphic rock. As shown in **Figure 4,** some metamorphic minerals form only at certain temperatures and pressures. These minerals, known as *index minerals,* are used to estimate the temperature, depth, and pressure at which a rock undergoes metamorphism. Index minerals include biotite mica, chlorite, garnet, kyanite, muscovite mica, sillimanite, and staurolite.

✓ *Reading Check* **What is an index mineral?**

Figure 4 *Scientists can understand a metamorphic rock's history by observing the minerals the rock contains. For example, a metamorphic rock that contains garnet formed at a greater depth and under greater heat and pressure than a rock that contains only chlorite.*



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Textures of Metamorphic Rock

You have learned that texture helps scientists classify igneous and sedimentary rock. The same is true of metamorphic rock. All metamorphic rock has one of two textures—foliated or nonfoliated. Take a closer look at each of these types of metamorphic rock to find out how each type forms.

foliated the texture of metamorphic rock in which the mineral grains are arranged in planes or bands

Foliated Metamorphic Rock

The texture of metamorphic rock in which the mineral grains are arranged in planes or bands is called **foliated.** Foliated metamorphic rock usually contains aligned grains of flat minerals, such as biotite mica or chlorite. Look at **Figure 5.** Shale is a sedimentary rock made of layers of clay minerals. When shale is exposed to slight heat and pressure, the clay minerals change into mica minerals. The shale becomes a foliated metamorphic rock called *slate*.

Metamorphic rocks can become other metamorphic rocks if the environment changes again. If slate is exposed to more heat and pressure, the slate can change into rock called *phyllite*. When phyllite is exposed to heat and pressure, it can change into *schist*.

If metamorphism continues, the arrangement of minerals in the rock changes. More heat and pressure cause minerals to separate into distinct bands in a metamorphic rock called *gneiss* (NIES).

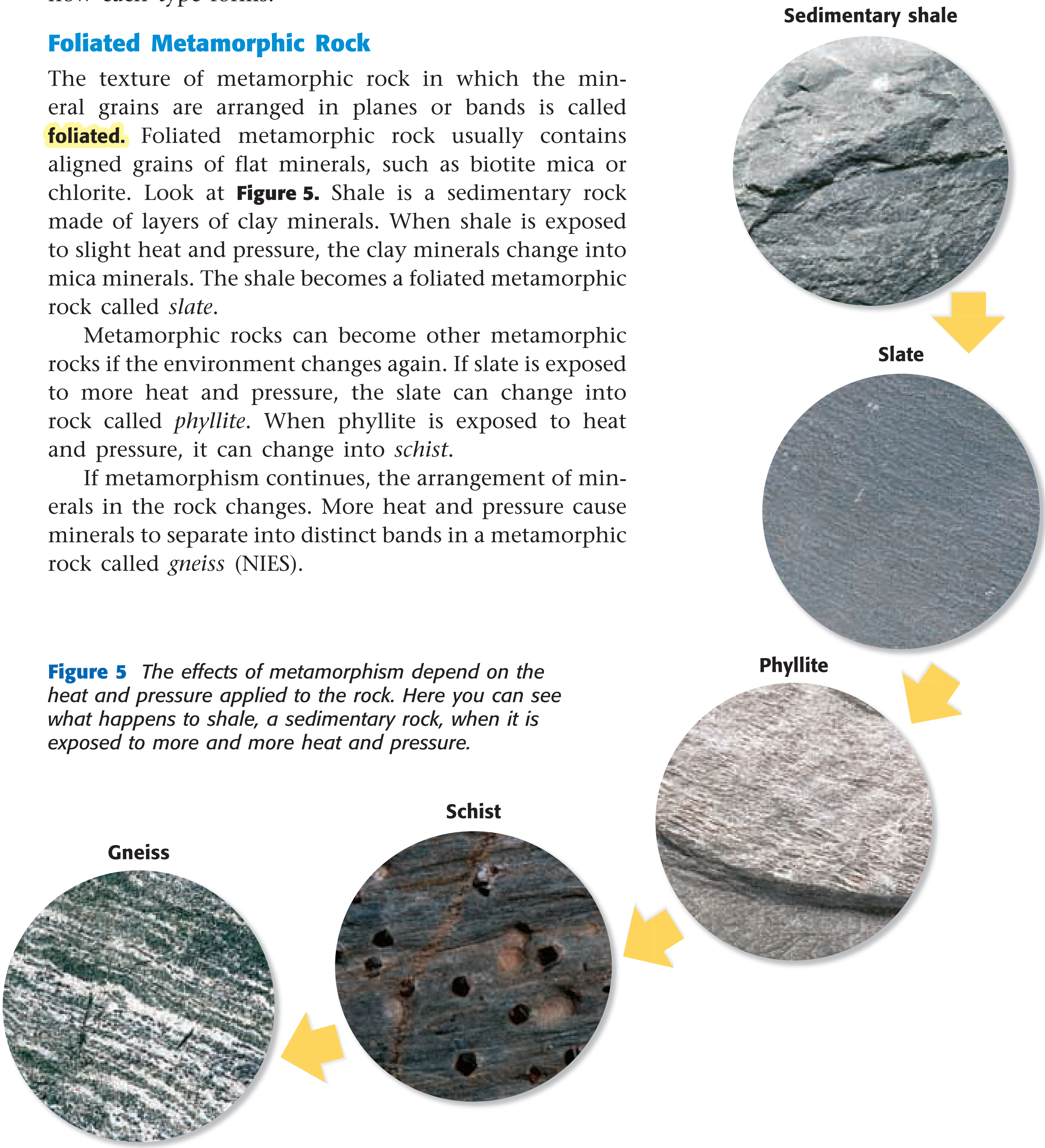


Figure 5 *The effects of metamorphism depend on the heat and pressure applied to the rock. Here you can see what happens to shale, a sedimentary rock, when it is exposed to more and more heat and pressure.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Nonfoliated Metamorphic Rock

The texture of metamorphic rock in which the mineral grains are not arranged in planes or bands is called **nonfoliated.** Notice that the rocks shown in **Figure 6** do not have mineral grains that are aligned. This lack of aligned mineral grains is the reason these rocks are called *nonfoliated rocks*.

Nonfoliated rocks are commonly made of one or only a few minerals. During metamorphism, the crystals of these minerals may change in size or the mineral may change in composition in a process called *recrystallization*. The quartzite and marble shown in **Figure 6** are examples of sedimentary rocks that have recrystallized during metamorphism.

Quartz sandstone is a sedimentary rock made of quartz sand grains that have been cemented together. When quartz sandstone is exposed to the heat and pressure, the spaces between the sand grains disappear as the grains recrystallize to form quartzite. Quartzite has a shiny, glittery appearance. Like quartz sandstone, it is made of quartz. But during recrystallization, the mineral grains have grown larger than the original grains in the sandstone.

When limestone undergoes metamorphism, the same process that happened to the quartz happens to the calcite, and the limestone becomes marble. The calcite crystals in the marble are larger than the calcite grains in the original limestone.

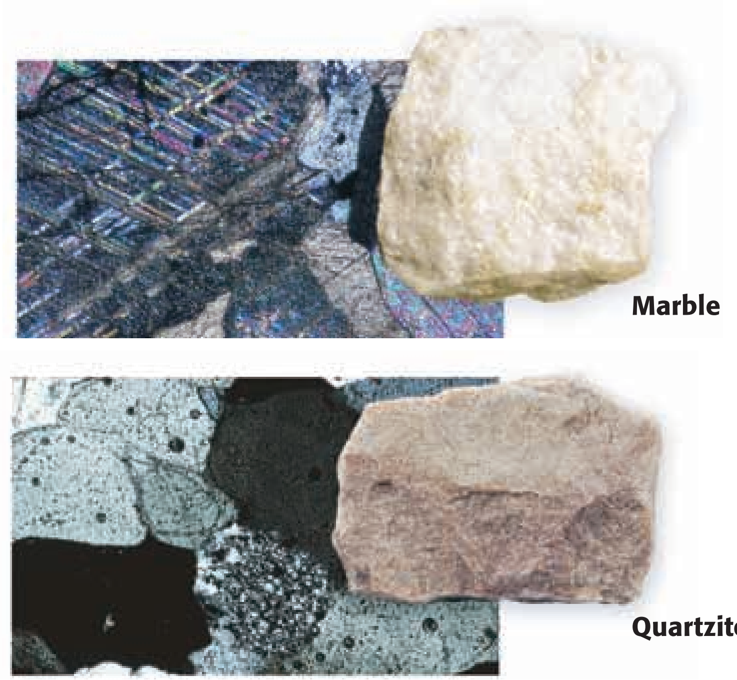
CONNECTION TO Biology

WRITING SKILL **Metamorphosis** The term *metamorphosis* means "change in form." When some animals undergo a dramatic change in the shape of their body, they are said to have undergone a metamorphosis. As part of their natural life cycle, moths and butterflies go through four stages. After they hatch from an egg, they are in the larval stage in the form of a caterpillar. In the next stage, they build a cocoon or become a chrysalis. This stage is called the *pupal stage*. They finally emerge into the adult stage of their life, in which they have wings, antennae, and legs! Research other animals that undergo a metamorphosis, and summarize your findings in a short essay.

nonfoliated the texture of metamorphic rock in which the mineral grains are not arranged in planes or bands

Figure 6 Two Examples of Nonfoliated Metamorphic Rock

Marble and quartzite are nonfoliated metamorphic rocks. As you can see in the views through a microscope, the mineral crystals are not well aligned.



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Metamorphic Rock Structures

Like igneous and sedimentary rock, metamorphic rock also has features that tell you about its history. In metamorphic rocks, these features are caused by deformation. *Deformation* is a change in the shape of a rock caused by a force placed on it. These forces may cause a rock to be squeezed or stretched.

Folds, or bends, in metamorphic rock are structures that indicate that a rock has been deformed. Some folds are not visible to the naked eye. But, as shown in **Figure 7,** some folds may be kilometers or even hundreds of kilometers in size.

Reading Check How are metamorphic rock structures related to deformation?

Figure 7 *These large folds occur in metamorphosed sedimentary rock along Saglet Fiord in Labrador, Canada.*

SECTION Review

Summary

- Metamorphic rocks are rocks in which the structure, texture, or composition has changed.
- Two ways rocks can undergo metamorphism are by contact metamorphism and regional metamorphism.
- As rocks undergo metamorphism, the original minerals in a rock change into new minerals that are more stable in new pressure and temperature conditions.
- Foliated metamorphic rock has mineral crystals aligned in planes or bands, whereas nonfoliated rocks have unaligned mineral crystals.
- Metamorphic rock structures are caused by deformation.

Using Key Terms

1. In your own words, define the following terms: *foliated* and *nonfoliated.*

Understanding Key Ideas

2. Which of the following is not a type of foliated metamorphic rock?
   a. gneiss
   b. slate
   c. marble
   d. schist
3. Explain the difference between contact metamorphism and regional metamorphism.
4. Explain how index minerals allow a scientist to understand the history of a metamorphic rock.

Math Skills

5. For every 3.3 km a rock is buried, the pressure placed upon it increases 0.1 gigapascal (100 million pascals). If rock undergoing metamorphosis is buried at 16 km, what is the pressure placed on that rock? (Hint: The pressure at Earth's surface is .101 gigapascal.)

Critical Thinking

6. **Making Inferences** If you had two metamorphic rocks, one that has garnet crystals and the other that has chlorite crystals, which one could have formed at a deeper level in the Earth's crust? Explain your answer.
7. **Applying Concepts** Which do you think would be easier to break, a foliated rock, such as slate, or a nonfoliated rock, such as quartzite? Explain.
8. **Analyzing Processes** A mountain range is located at a boundary where two tectonic plates are colliding. Would most of the metamorphic rock in the mountain range be a product of contact metamorphism or regional metamorphism? Explain.

SCILINKS® NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Metamorphic Rock
SciLinks code: HSM0949

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Skills Practice Lab

Let's Get Sedimental

How do we determine if sedimentary rock layers are undisturbed? The best way to do this is to be sure that fine-grained sediments near the top of a layer lie above coarse-grained sediments near the bottom of the layer. This lab activity will show you how to read rock features that will help you distinguish individual sedimentary rock layers. Then, you can look for the features in real rock layers.

OBJECTIVES

Model the process of sedimentation.

Determine whether sedimentary rock layers are undisturbed.

MATERIALS

- clay
- dropper pipet
- gravel
- magnifying lens
- mixing bowl, 2 qt
- sand
- scissors
- soda bottle with a cap, plastic, 2 L
- soil, clay rich, if available
- water

SAFETY

Procedure

1. In a mixing bowl, thoroughly mix the sand, gravel, and soil. Fill the soda bottle about one-third full of the mixture.
2. Add water to the soda bottle until the bottle is two-thirds full. Twist the cap back onto the bottle, and shake the bottle vigorously until all of the sediment is mixed in the rapidly moving water.
3. Place the bottle on a tabletop. Using the scissors, carefully cut the top off the bottle a few centimeters above the water, as shown. The open bottle will allow water to evaporate.
4. Immediately after you set the bottle on the tabletop, describe what you see from above and through the sides of the bottle.
5. Do not disturb the container. Allow the water to evaporate. (You may speed up the process by carefully using the dropper pipet to siphon off some of the clear water after you allow the container to sit for at least 24 hours.) You may also set the bottle in the sun or under a desk lamp to speed up evaporation.
6. After the sediment has dried and hardened, describe its surface.
7. Carefully lay the container on its side, and cut a wide, vertical strip of plastic down the length of the bottle to expose the sediments in the container. You may find it easier if you place pieces of clay on either side of the container to stabilize it. (If the bottle is clear along its length, this step may not be required.)
8. Brush away the loose material from the sediment, and gently blow on the surface until it is clean. Examine the surface, and record your observations.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Analyze the Results

1. **Identifying Patterns** Do you see anything through the side of the bottle that could help you determine if a sedimentary rock is undisturbed? Explain your answer.

2. **Identifying Patterns** Can you observe a pattern of deposition? If so, describe the pattern of deposition of sediment that you observe from top to bottom.

3. **Explaining Events** Explain how these features might be used to identify the top of a sedimentary layer in real rock and to decide if the layer has been disturbed.

4. **Identifying Patterns** Do you see any structures through the side of the bottle that might indicate which direction is up, such as a change in particle density or size?

5. **Identifying Patterns** Use the magnifying lens to examine the boundaries between the gravel, sand, and silt. Do the size of the particles and the type of sediment change dramatically in each layer?

Draw Conclusions

6. **Making Predictions** Imagine that a layer was deposited directly above the sediment in your bottle. Describe the composition of this new layer. Will it have the same composition as the mixture in steps 1–5 in the Procedure?

Applying Your Data

With your class or with a parent, visit an outcrop of sedimentary rock. Apply the information that you have learned in this lab to see if you can determine whether the sedimentary rock layers are disturbed or undisturbed.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Chapter Review

USING KEY TERMS

1 In your own words, write a definition for the term *rock cycle*.

Complete each of the following sentences by choosing the correct term from the word bank.

stratification	foliated
extrusive igneous rock	texture

2 The ___ of a rock is determined by the sizes, shapes, and positions of the minerals the rock contains.

3 ___ metamorphic rock contains minerals that are arranged in plates or bands.

4 The most characteristic property of sedimentary rock is ___.

5 ___ forms plains called *lava plateaus*.

UNDERSTANDING KEY IDEAS

Multiple Choice

6 Sedimentary rock is classified into all of the following main categories except

a. clastic sedimentary rock.
b. chemical sedimentary rock.
c. nonfoliated sedimentary rock.
d. organic sedimentary rock.

7 An igneous rock that cools very slowly has a ___ texture.

a. foliated
b. fine-grained
c. nonfoliated
d. coarse-grained

8 Igneous rock forms when

a. minerals crystallize from a solution.
b. sand grains are cemented together.
c. magma cools and solidifies.
d. mineral grains in a rock recrystallize.

9 A ___ is a common structure found in metamorphic rock.

a. ripple mark **c.** sill
b. fold **d.** layer

10 The process in which sediment is removed from its source and transported is called

a. deposition. **c.** weathering.
b. erosion. **d.** uplift.

11 Mafic rocks are

a. light-colored rocks rich in calcium, iron, and magnesium.
b. dark-colored rocks rich in aluminum, potassium, silica, and sodium.
c. light-colored rocks rich in aluminum, potassium, silica, and sodium.
d. dark-colored rocks rich in calcium, iron, and magnesium.

Short Answer

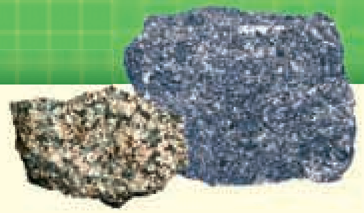
12 Explain how composition and texture are used by scientists to classify rocks.

13 Describe two ways a rock can undergo metamorphism.

14 Explain why some minerals only occur in metamorphic rocks.

15 Describe how each type of rock changes as it moves through the rock cycle.

Copyright © by Holt, Rinehart and Winston. All rights reserved.



16. Describe two ways rocks were used by early humans and ancient civilizations.

CRITICAL THINKING

17. **Concept Mapping** Use the following terms to construct a concept map: *rocks, metamorphic, sedimentary, igneous, foliated, nonfoliated, organic, clastic, chemical, intrusive,* and *extrusive.*

18. **Making Inferences** If you were looking for fossils in the rocks around your home and the rock type that was closest to your home was metamorphic, do you think that you would find many fossils? Explain your answer.

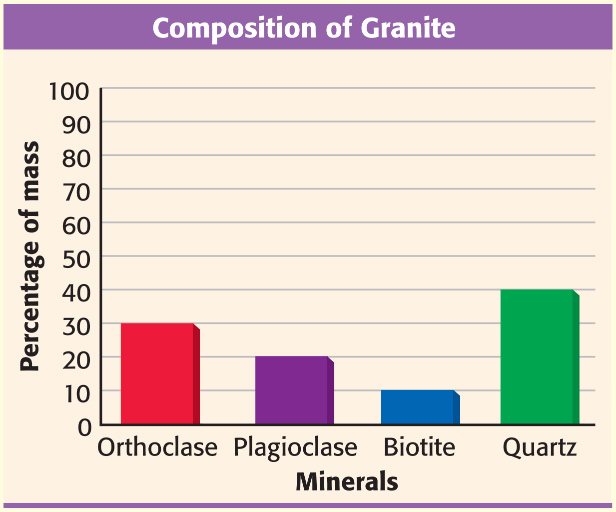
19. **Applying Concepts** Imagine that you want to quarry, or mine, granite. You have all of the equipment, but you have two pieces of land to choose from. One area has a granite batholith underneath it. The other has a granite sill. If both intrusive bodies are at the same depth, which one would be the better choice for you to quarry? Explain your answer.

20. **Applying Concepts** The sedimentary rock coquina is made up of pieces of seashells. Which of the three kinds of sedimentary rock could coquina be? Explain your answer.

21. **Analyzing Processes** If a rock is buried deep inside the Earth, which geological processes cannot change the rock? Explain your answer.

INTERPRETING GRAPHICS

The bar graph below shows the percentage of minerals by mass that compose a sample of granite. Use the graph below to answer the questions that follow.



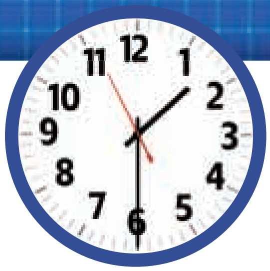
22. Your rock sample is made of four minerals. What percentage of each mineral makes up your sample?

23. Both plagioclase and orthoclase are feldspar minerals. What percentage of the minerals in your sample of granite are not feldspar minerals?

24. If your rock sample has a mass of 10 g, how many grams of quartz does it contain?

25. Use paper, a compass, and a protractor or a computer to make a pie chart. Show the percentage of each of the four minerals your sample of granite contains. (Look in the Appendix of this book for help on making a pie chart.)

Copyright © by Holt, Rinehart and Winston. All rights reserved.



Standardized Test Preparation

EOG Prep

READING

Read each of the passages below. Then, answer the questions that follow each passage.

Passage 1 The texture and composition of a rock can provide good clues about how and where the rock formed. Scientists use both texture and composition to understand the origin and history of rocks. For example, marble is a rock that is made when limestone is metamorphosed. Only limestone contains the mineral—calcite—that can change into marble. Therefore, wherever scientists find marble, they know the sediment that created the original limestone was deposited in a warm ocean or lake environment.

1. In the passage, what does the word *origin* mean?

A size or appearance
B age
C location or surroundings
D source or formation

2. Based on the passage, what can the reader conclude?

F Marble is a sedimentary rock.
G Limestone is created by sediments deposited in warm ocean or lake environments.
H Marble is a rock that is made when sandstone has undergone metamorphism.
I In identifying a rock, the texture of a rock is more important than the composition of the rock.

3. What is the main idea of the passage?

A Scientists believe marble is the most important rock type to study.
B Scientists study the composition and texture of a rock to determine how the rock formed and what happened after it formed.
C Some sediments are deposited in warm oceans and lakes.
D When limestone undergoes metamorphism, it creates marble.

Passage 2 Fulgurites are a rare type of natural glass found in areas that have quartz-rich sediments, such as beaches and deserts. A tubular fulgurite forms when a lightning bolt strikes material such as sand and melts the quartz into a liquid. The liquid quartz cools and solidifies quickly, and a thin, glassy tube is left behind. Fulgurites usually have a rough outer surface and a smooth inner surface. Underground, a fulgurite may be shaped like the roots of a tree. The fulgurite branches out with many arms that trace the zigzag path of the lightning bolt. Some fulgurites are as short as your little finger, but others stretch 20 m into the ground.

1. In the passage, what does the word *tubular* mean?

A flat and sharp
B round and long
C funnel shaped
D pyramid shaped

2. From the information in the passage, what can the reader conclude?

F Fulgurites are formed above ground.
G Sand contains a large amount of quartz.
H Fulgurites are most often very small.
I Fulgurites are easy to find in sandy places.

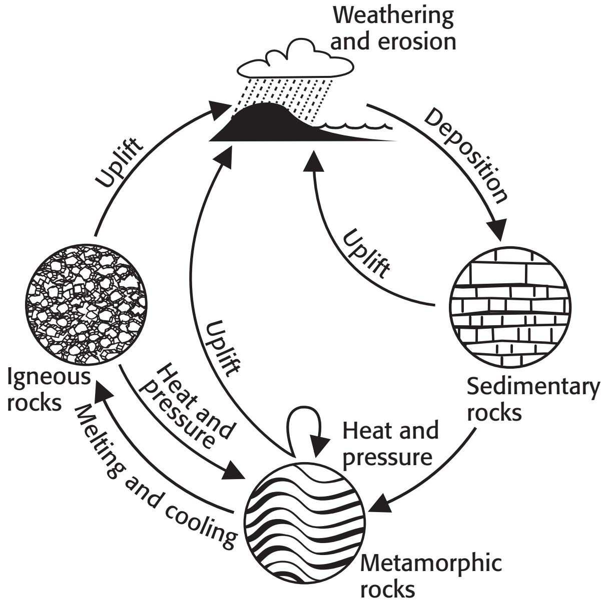
3. Which of the following statements best describes a fulgurite?

A Fulgurites are frozen lightning bolts.
B Fulgurites are rootlike rocks.
C Fulgurites are glassy tubes found in deserts.
D Fulgurites are natural glass tubes formed by lightning bolts.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

INTERPRETING GRAPHICS

Use the diagram below to answer the questions that follow.



1. According to the rock cycle diagram, which of the following statements is true?

A Only sedimentary rock gets weathered and eroded.
B Sedimentary rocks are made from metamorphic, igneous, and sedimentary rock fragments and minerals.
C Heat and pressure create igneous rocks.
D Metamorphic rocks are created by melting and cooling.

2. A rock exists at the surface of the Earth. What would be the next step in the rock cycle?

F cooling
G weathering
H melting
I metamorphism

3. Which of the following processes brings rocks to Earth's surface, where they can be eroded?

A burial
B deposition
C uplift
D weathering

4. Which of the following is the best summary of the rock cycle?

F Each type of rock gets melted. Then the magma turns into igneous, sedimentary, and metamorphic rock.
G Magma cools to form igneous rock. Then, the igneous rock becomes sedimentary rock. Sedimentary rock is heated and forms metamorphic rock. Metamorphic rock melts to form magma.
H All three rock types weather to create sedimentary rock. All three rock types melt to form magma. Magma forms igneous rock. All three types of rock form metamorphic rock because of heat and pressure.
I Igneous rock is weathered to create sedimentary rock. Sedimentary rock is melted to form igneous rock. Metamorphic rock is weathered to form igneous rock.

MATH

Read each question below, and choose the best answer.

1. Eric has 25 rocks he has collected as a science project for class. Nine rocks are sedimentary, 10 are igneous, and 6 are metamorphic. If Eric chooses a rock at random, what is the probability that he will choose an igneous rock?

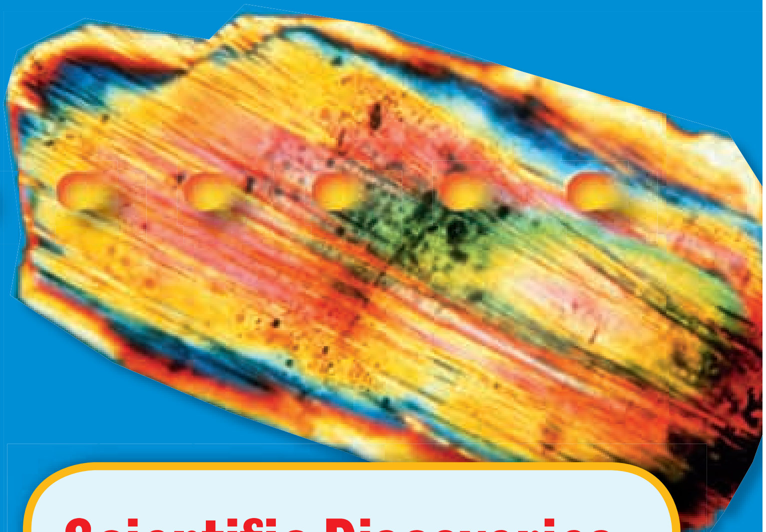
A 1/2
B 2/5
C 3/8
D 1/15

2. At a mineral and fossil show, Elizabeth bought two quartz crystals that cost \$2.00 each and four trilobite fossils that cost \$3.50 each. Which equation can be used to describe c, the total cost of her purchase?

F $c = (2 \times 4) + (2.00 \times 3.50)$
G $c = (2 \times 2.00) + (4 \times 3.50)$
H $c = (4 \times 2.00) + (2 \times 3.50)$
I $c = (2 + 2.00) + (4 + 3.50)$

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Science in Action



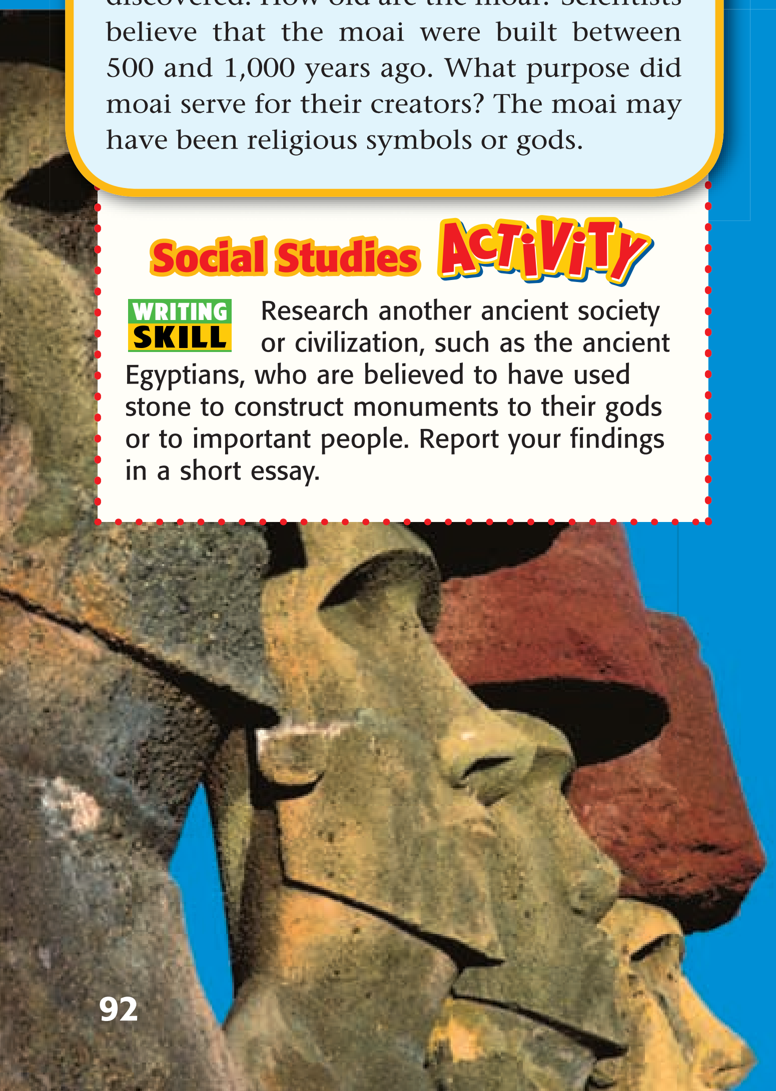
Science, Technology, and Society

The Moai of Easter Island

Easter island is located in the Pacific Ocean more than 3,200 km from the coast of Chile. The island is home to mysterious statues that were carved from volcanic ash. The statues, called *moai,* have human heads and large torsos. The average moai weighs 14 tons and is more than 4.5 m tall, though some are as tall as 10 m! Altogether, 887 moai have been discovered. How old are the moai? Scientists believe that the moai were built between 500 and 1,000 years ago. What purpose did moai serve for their creators? The moai may have been religious symbols or gods.

Social Studies ACTIVITY

WRITING SKILL Research another ancient society or civilization, such as the ancient Egyptians, who are believed to have used stone to construct monuments to their gods or to important people. Report your findings in a short essay.



Scientific Discoveries

Shock Metamorphism

When a large asteroid, meteoroid, or comet collides with the Earth, extremely high temperatures and pressures are created in Earth's surface rock. These high pressures and temperatures cause minerals in the surface rock to shatter and recrystallize. The new minerals that result from this recrystallization cannot be created under any other conditions. This process is called *shock metamorphism.*

When large objects from space collide with the Earth, craters are formed by the impact. However, impact craters are not always easy to find on Earth. Scientists use shock metamorphism as a clue to locate ancient impact craters.

Language Arts ACTIVITY

WRITING SKILL The impact site caused by the asteroid strike in the Yucatán 65 million years ago has been named the Chicxulub (cheeks OO loob) structure. Research the origin of the name Chicxulub, and report your findings in a short paper.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Robert L. Folk

Petrologist For Dr. Robert Folk, the study of rock takes place on the microscopic level. Dr. Folk is searching for tiny life-forms he has named nannobacteria, or dwarf bacteria, in rock. *Nannobacteria* may also be spelled *nanobacteria*. Because nannobacteria are so incredibly small, only 0.05 to 0.2 µm in diameter, Folk must use an extremely powerful 100,000× microscope, called a *scanning electron microscope,* to see the shape of the bacteria in rock. Folk's research had already led him to discover that a certain type of Italian limestone is produced by bacteria. The bacteria were consuming the minerals, and the waste of the bacteria was forming the limestone. Further research led Folk to the discovery of the tiny nannobacteria. The spherical or oval-shaped nannobacteria appeared as chains and grapelike clusters. From his research, Folk hypothesized that nannobacteria are responsible for many inorganic reactions that occur in rock. Many scientists are skeptical of Folk's nannobacteria. Some skeptics believe that the tiny size of nannobacteria makes the bacteria simply too small to contain the chemistry of life. Others believe that nannobacteria actually represent structures that do not come from living things.

Math Activity

If a nannobacterium is 1/10 the length, 1/10 the width, and 1/10 the height of an ordinary bacterium, how many nannobacteria can fit within an ordinary bacterium? (Hint: Draw block diagrams of both a nannobacterium and an ordinary bacterium.)

go.hrw.com

To learn more about these Science in Action topics, visit **go.hrw.com** and type in the keyword **HZ5RCKF.**

Current Science

Check out Current Science® articles related to this chapter by visiting go.hrw.com. Just type in the keyword HZ5CS04.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

4

Plate Tectonics

About the PHOTO

The San Andreas fault stretches across the California landscape like a giant wound. The fault, which is 1,000 km long, breaks the Earth's crust from Northern California to Mexico. Because the North American plate and Pacific plate are slipping past one another along the fault, many earthquakes happen.

PRE-READING ACTIVITY

FOLDNOTES **Key-Term Fold** Before you read the chapter, create the FoldNote entitled "Key-Term Fold" described in the **Study Skills** section of the Appendix. Write a key term from the chapter on each tab of the key-term fold. Under each tab, write the definition of the key term.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

START-UP ACTIVITY

Continental Collisions

As you can see, continents not only move but can also crash into each other. In this activity, you will model the collision of two continents.

Procedure

1. Obtain **two stacks of paper** that are each about 1 cm thick.
2. Place the two stacks of paper on a **flat surface,** such as a desk.
3. Very slowly, push the stacks of paper together so that they collide. Continue to push the stacks until the paper in one of the stacks folds over.

Analysis

1. What happens to the stacks of paper when they collide with each other?
2. Are all of the pieces of paper pushed upward? If not, what happens to the pieces that are not pushed upward?
3. What type of landform will most likely result from this continental collision?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 1

Inside the Earth

If you tried to dig to the center of the Earth, what do you think you would find? Would the Earth be solid or hollow? Would it be made of the same material throughout?

READING WARM-UP

Objectives

- Identify the layers of the Earth by their composition.
- Identify the layers of the Earth by their physical properties.
- Describe a tectonic plate.
- Explain how scientists know about the structure of Earth's interior.

Terms to Learn

crust
mantle
core
lithosphere
asthenosphere
mesosphere
tectonic plate

READING STRATEGY

Reading Organizer As you read this section, create an outline of the section. Use the headings from the section in your outline.

Actually, the Earth is made of several layers. Each layer is made of different materials that have different properties. Scientists think about physical layers in two ways—by their composition and by their physical properties.

The Composition of the Earth

The Earth is divided into three layers—the crust, the mantle, and the core—based on the compounds that make up each layer. A *compound* is a substance composed of two or more elements. The less dense compounds make up the crust and mantle, and the densest compounds make up the core. The layers form because heavier elements are pulled toward the center of the Earth by gravity, and elements of lesser mass are found farther from the center.

The Crust

The outermost layer of the Earth is the **crust.** The crust is 5 to 100 km thick. It is the thinnest layer of the Earth.

As **Figure 1** shows, there are two types of crust—continental and oceanic. Both continental crust and oceanic crust are made mainly of the elements oxygen, silicon, and aluminum. However, the denser oceanic crust has almost twice as much iron, calcium, and magnesium, which form minerals that are denser than those in the continental crust.

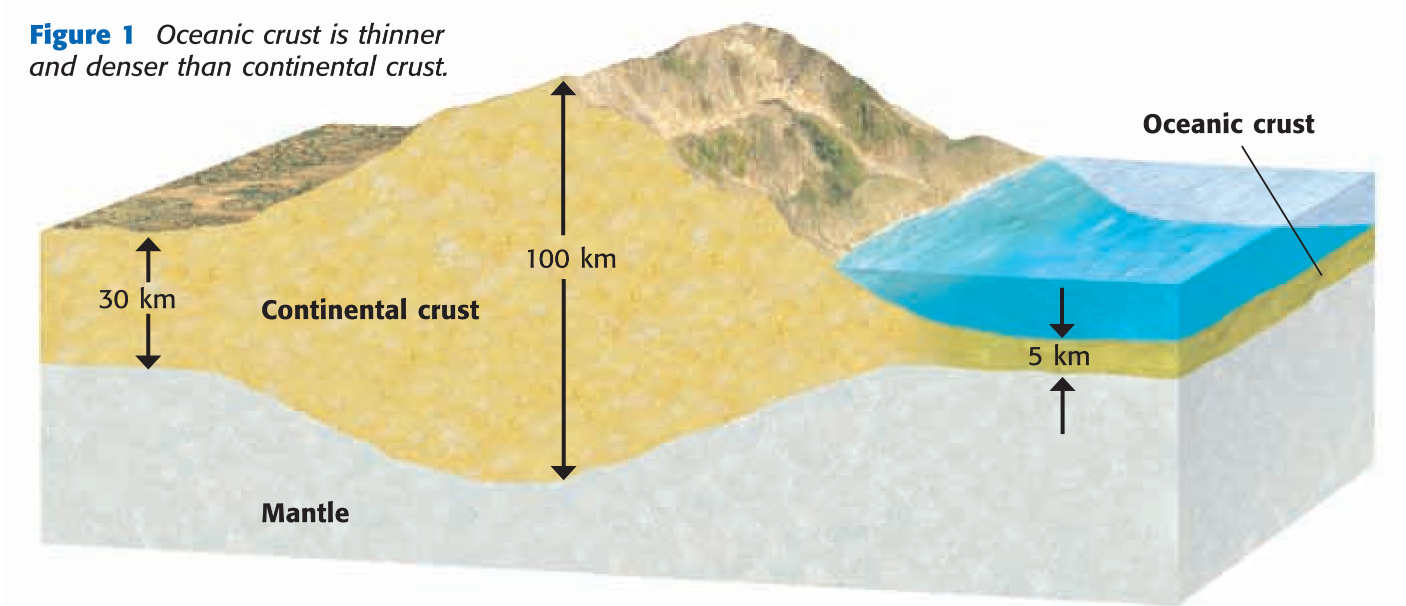


Figure 1 *Oceanic crust is thinner and denser than continental crust.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

The Mantle

The layer of the Earth between the crust and the core is the **mantle.** The mantle is much thicker than the crust and contains most of the Earth's mass.

No one has ever visited the mantle. The crust is too thick to drill through to reach the mantle. Scientists must draw conclusions about the composition and other physical properties of the mantle from observations made on the Earth's surface. In some places, mantle rock pushes to the surface, which allows scientists to study the rock directly.

As you can see in **Figure 2,** another place scientists look for clues about the mantle is the ocean floor. Magma from the mantle flows out of active volcanoes on the ocean floor. These underwater volcanoes have given scientists many clues about the composition of the mantle. Because the mantle has more magnesium and less aluminum and silicon than the crust does, the mantle is denser than the crust.

Figure 2 *Volcanic vents on the ocean floor, such as this vent off the coast of Hawaii, allow magma to rise up through the crust from the mantle.*

The Core

The layer of the Earth that extends from below the mantle to the center of the Earth is the **core.** Scientists think that the Earth's core is made mostly of iron and contains smaller amounts of nickel but almost no oxygen, silicon, aluminum, or magnesium. As shown in **Figure 3,** the core makes up roughly one-third of the Earth's mass.

crust the thin and solid outermost layer of the Earth above the mantle

mantle the layer of rock between the Earth's crust and core

core the central part of the Earth below the mantle

Reading Check **Briefly describe the layers that make up the Earth.** (*See the Appendix for answers to Reading Checks.*)

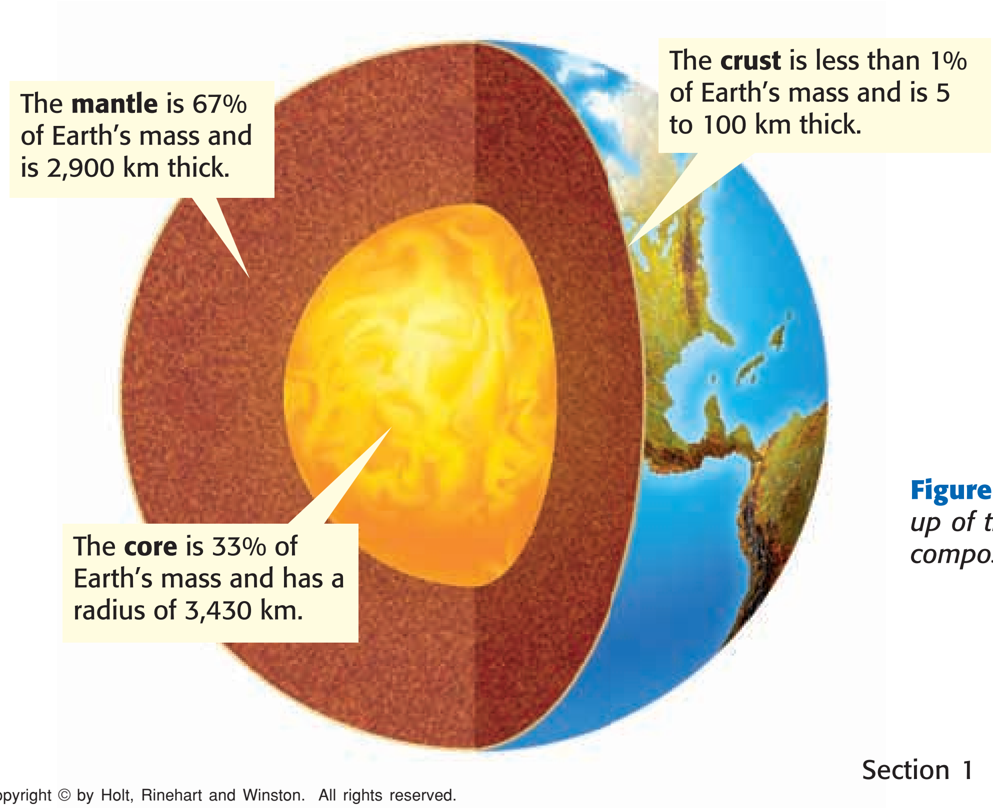


Figure 3 *The Earth is made up of three layers based on the composition of each layer.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

MATH PRACTICE

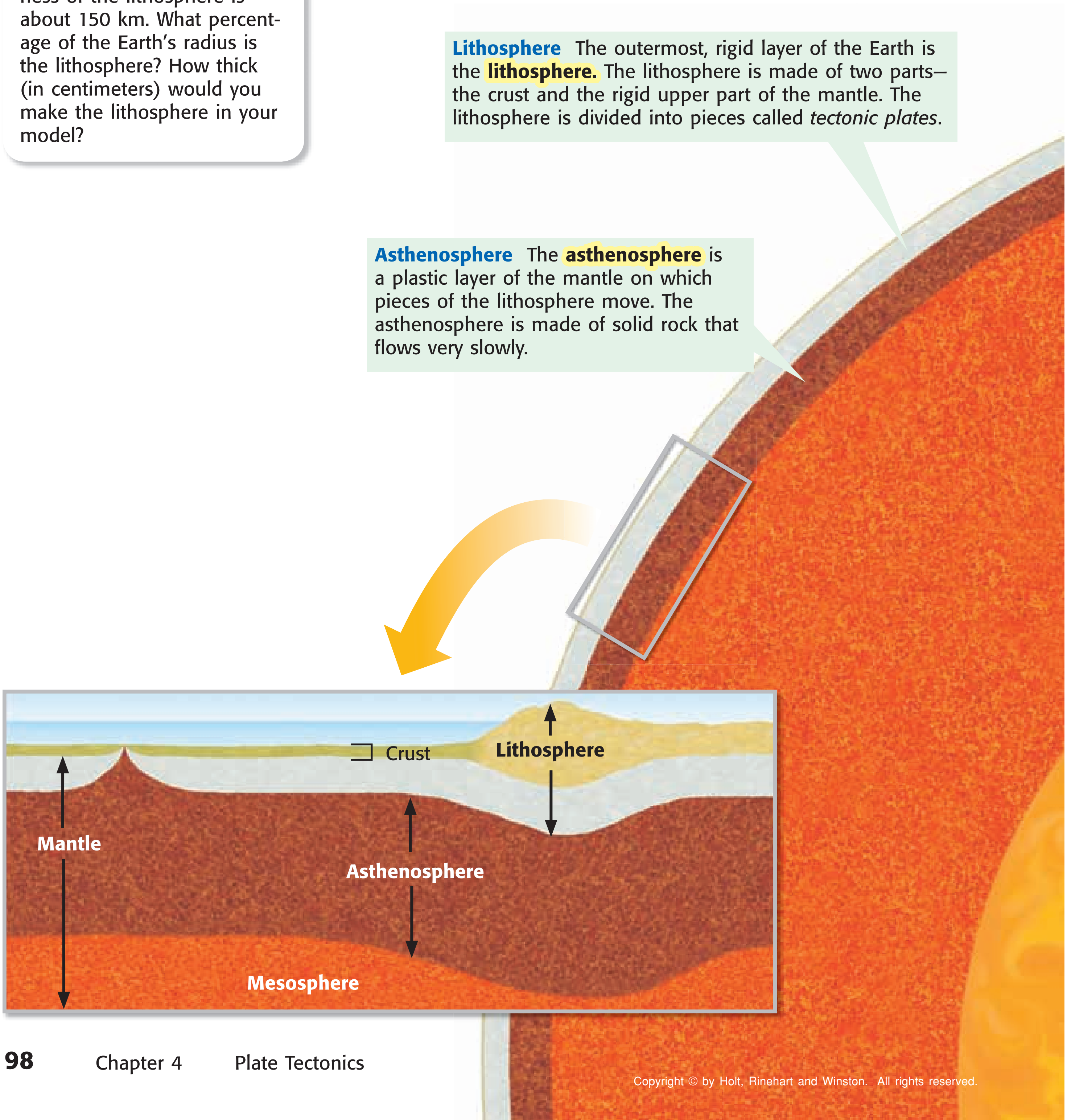
Using Models

Imagine that you are building a model of the Earth that will have a radius of 1 m. You find out that the average radius of the Earth is 6,380 km and that the thickness of the lithosphere is about 150 km. What percentage of the Earth's radius is the lithosphere? How thick (in centimeters) would you make the lithosphere in your model?

The Physical Structure of the Earth

Another way to look at the Earth is to examine the physical properties of its layers. The Earth is divided into five physical layers—the lithosphere, asthenosphere, mesosphere, outer core, and inner core. As shown in the figure below, each layer has its own set of physical properties.

Reading Check **What are the five physical layers of the Earth?**



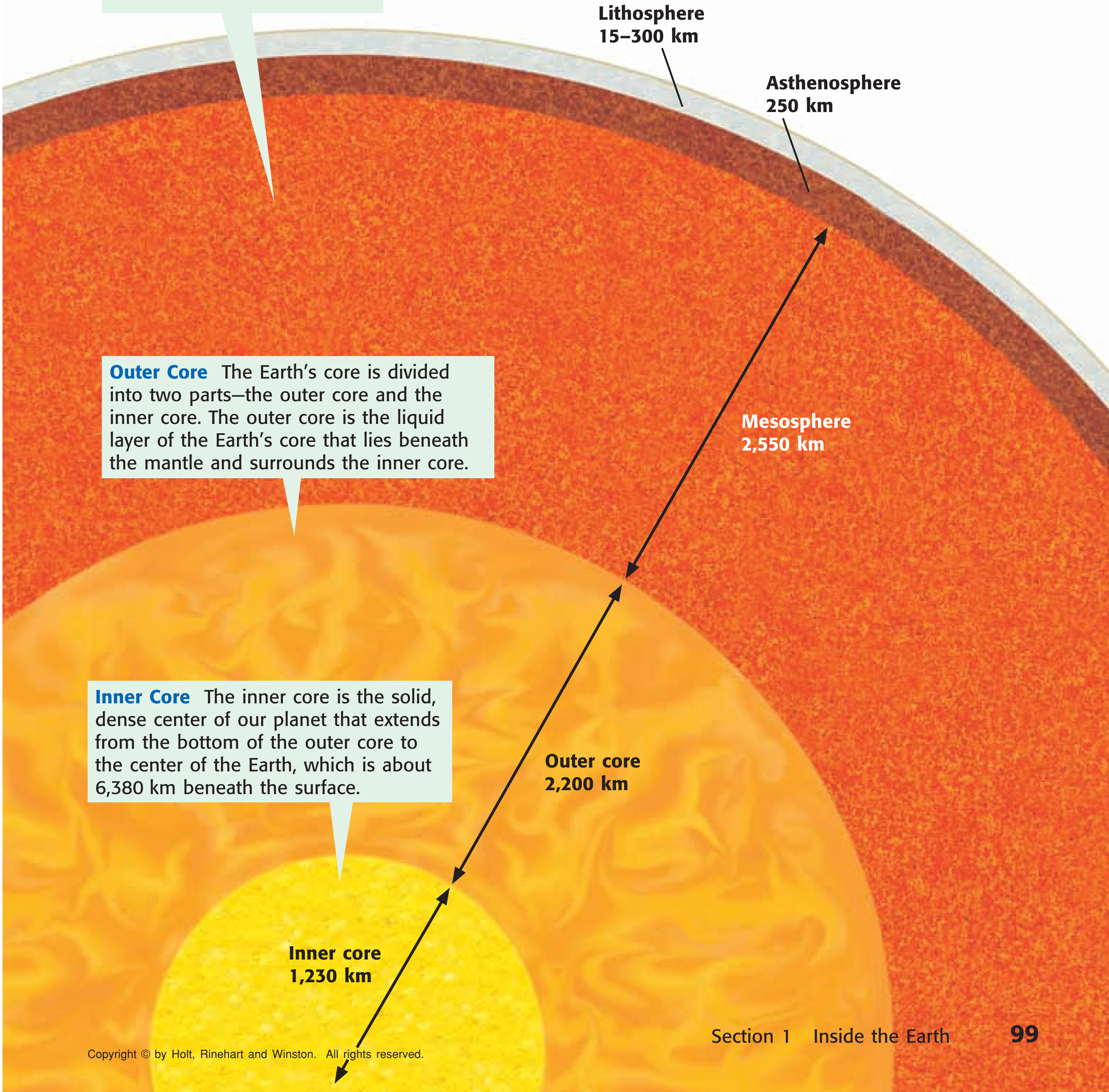
Copyright © by Holt, Rinehart and Winston. All rights reserved.

lithosphere the solid, outer layer of the Earth that consists of the crust and the rigid upper part of the mantle

asthenosphere the soft layer of the mantle on which the tectonic plates move

mesosphere the strong, lower part of the mantle between the asthenosphere and the outer core

Mesosphere Beneath the asthenosphere is the strong, lower part of the mantle called the **mesosphere.** The mesosphere extends from the bottom of the asthenosphere to the Earth's core.



Outer Core The Earth's core is divided into two parts—the outer core and the inner core. The outer core is the liquid layer of the Earth's core that lies beneath the mantle and surrounds the inner core.

Inner Core The inner core is the solid, dense center of our planet that extends from the bottom of the outer core to the center of the Earth, which is about 6,380 km beneath the surface.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Tectonic Plates

tectonic plate a block of lithosphere that consists of the crust and the rigid, outermost part of the mantle

Pieces of the lithosphere that move around on top of the asthenosphere are called **tectonic plates**. But what exactly does a tectonic plate look like? How big are tectonic plates? How and why do they move around? To answer these questions, begin by thinking of the lithosphere as a giant jigsaw puzzle.

A Giant Jigsaw Puzzle

All of the tectonic plates have names, some of which you may already know. Some of the major tectonic plates are named on the map in **Figure 4.** Notice that each tectonic plate fits together with the tectonic plates that surround it. The lithosphere is like a jigsaw puzzle, and the tectonic plates are like the pieces of a jigsaw puzzle.

Notice that not all tectonic plates are the same. For example, compare the size of the South American plate with that of the Cocos plate. Tectonic plates differ in other ways, too. For example, the South American plate has an entire continent on it and has oceanic crust, but the Cocos plate has only oceanic crust. Some tectonic plates, such as the South American plate, include both continental and oceanic crust.

Major Tectonic Plates

1. Pacific plate
2. North American plate
3. Cocos plate
4. Nazca plate
5. South American plate
6. African plate
7. Eurasian plate
8. Indian plate
9. Australian plate
10. Antarctic plate

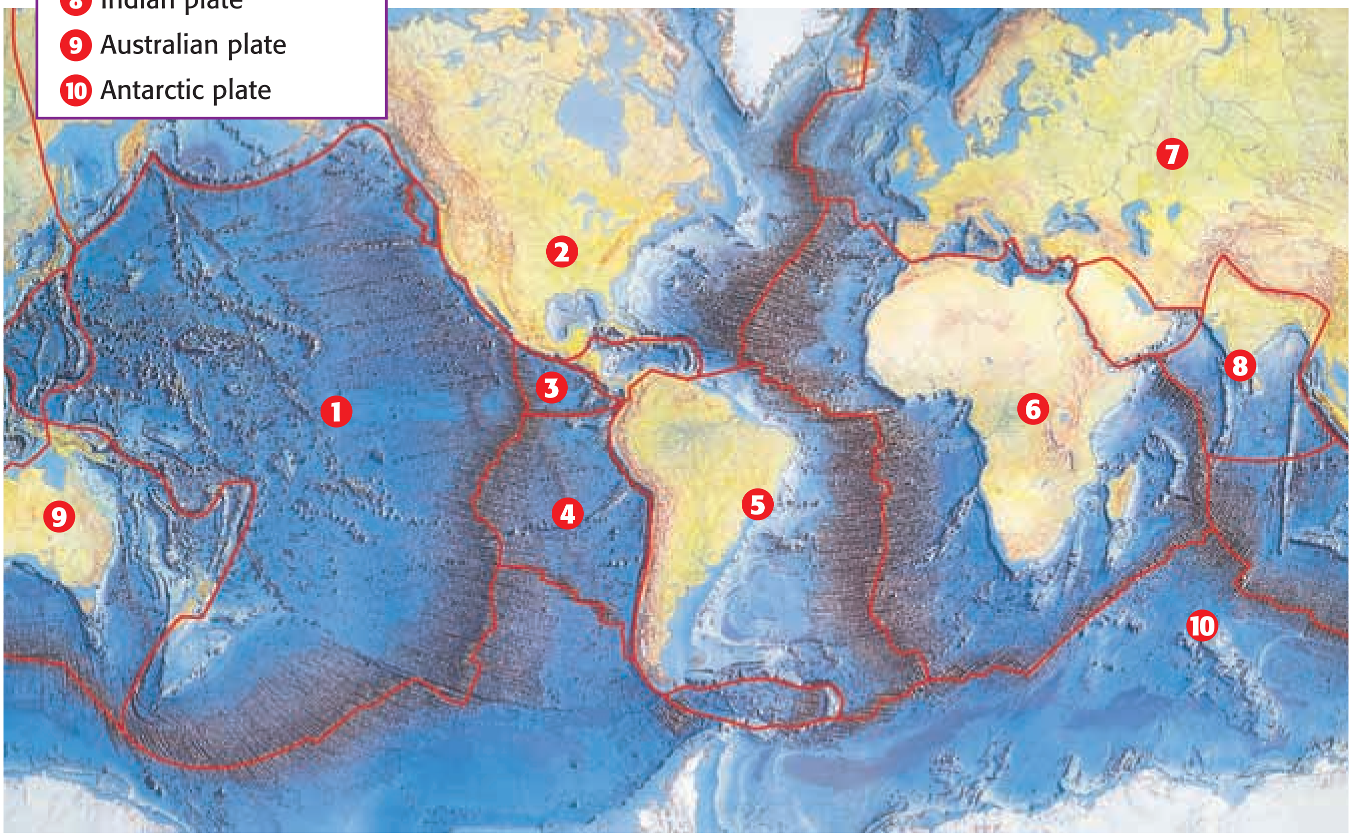
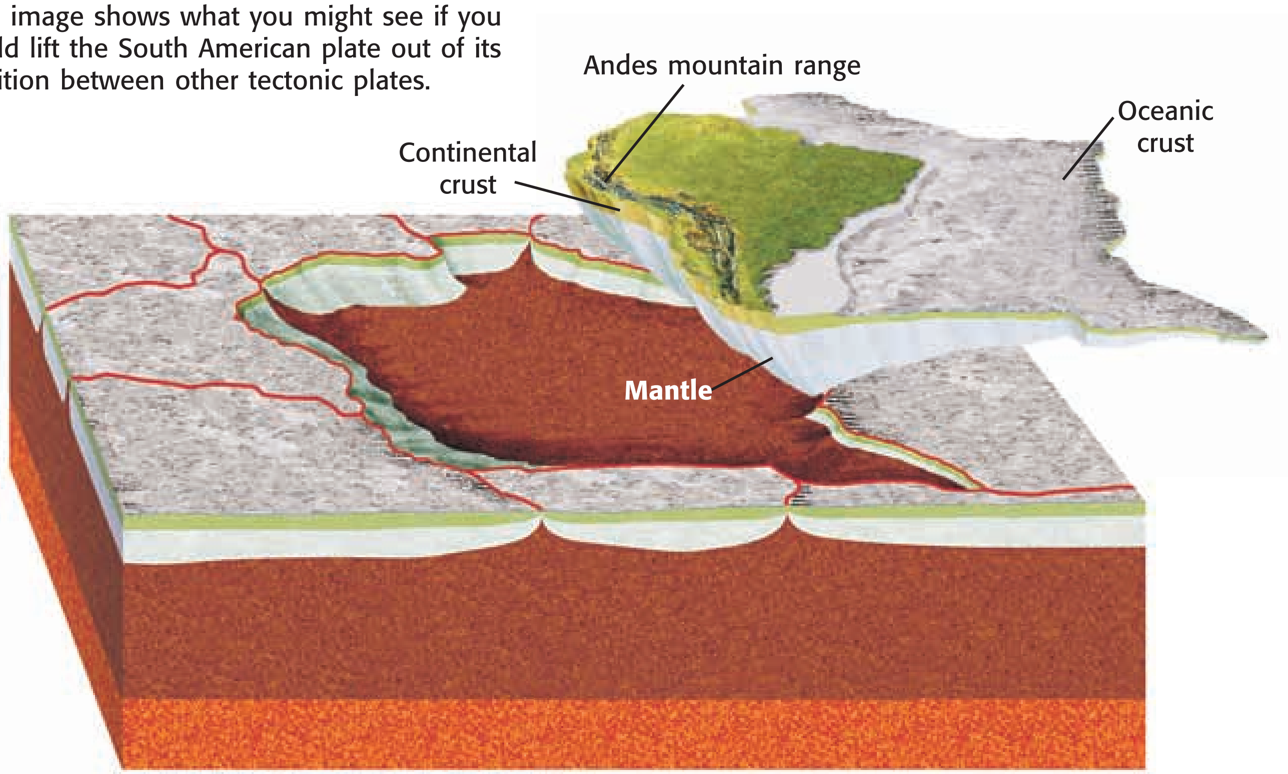


Figure 4 *Tectonic plates fit together like the pieces of a giant jigsaw puzzle.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 5 The South American Plate

This image shows what you might see if you could lift the South American plate out of its position between other tectonic plates.



A Tectonic Plate Close-Up

What would a tectonic plate look like if you could lift it out of its place? **Figure 5** shows what the South American plate might look like if you could. Notice that this tectonic plate not only consists of the upper part of the mantle but also consists of both oceanic crust and continental crust. The thickest part of the South American plate is the continental crust. The thinnest part of this plate is in the mid-Atlantic Ocean.

Like Ice Cubes in a Bowl of Punch

Think about ice cubes floating in a bowl of punch. If there are enough cubes, they will cover the surface of the punch and bump into one another. Parts of the ice cubes are below the surface of the punch and displace the punch. Large pieces of ice displace more punch than small pieces of ice. Tectonic plates "float" on the asthenosphere in a similar way. The plates cover the surface of the asthenosphere, and they touch one another and move around. The lithosphere displaces the asthenosphere. Thick tectonic plates, such as those made of continental crust, displace more asthenosphere than do thin plates, such as those made of oceanic lithosphere.

Reading Check **Why do tectonic plates made of continental lithosphere displace more asthenosphere than tectonic plates made of oceanic lithosphere do?**

Quick Lab

Tectonic Ice Cubes

1. Take the bottom half of a clear, **2 L soda bottle** that has been cut in half. Make sure that the label has been removed.
2. Fill the bottle with **water** to about 1 cm below the top edge of the bottle.
3. Get **three pieces of irregularly shaped ice** that are small, medium, and large.
4. Float the ice in the water, and note how much of each piece is below the surface of the water.
5. Do all pieces of ice float mostly below the surface? Which piece is mostly below the surface? Why?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SCHOOL to HOME

Build a Seismograph

Seismographs are instruments that seismologists, scientists who study earthquakes, use to detect seismic waves. Research seismograph designs with your parent. For example, a simple seismograph can be built by using a weight suspended by a spring next to a ruler. With your parent, attempt to construct a home seismograph based on a design you have selected. Outline each of the steps used to build your seismograph, and present the written outline to your teacher.

ACTIVITY

Mapping the Earth's Interior

How do scientists know things about the deepest parts of the Earth, where no one has ever been? Scientists have never even drilled through the crust, which is only a thin skin on the surface of the Earth. So, how do we know so much about the mantle and the core?

Would you be surprised to know that some of the answers come from earthquakes? When an earthquake happens, vibrations called *seismic waves* are produced. Seismic waves travel at different speeds through the Earth. Their speed depends on the density and composition of material that they pass through. For example, a seismic wave traveling through a solid will go faster than a seismic wave traveling through a liquid.

When an earthquake happens, machines called *seismographs* measure the times at which seismic waves arrive at different distances from an earthquake. Seismologists can then use these distances and travel times to calculate the density and thickness of each physical layer of the Earth. **Figure 6** shows how seismic waves travel through the Earth.

Reading Check **What are some properties of seismic waves?**

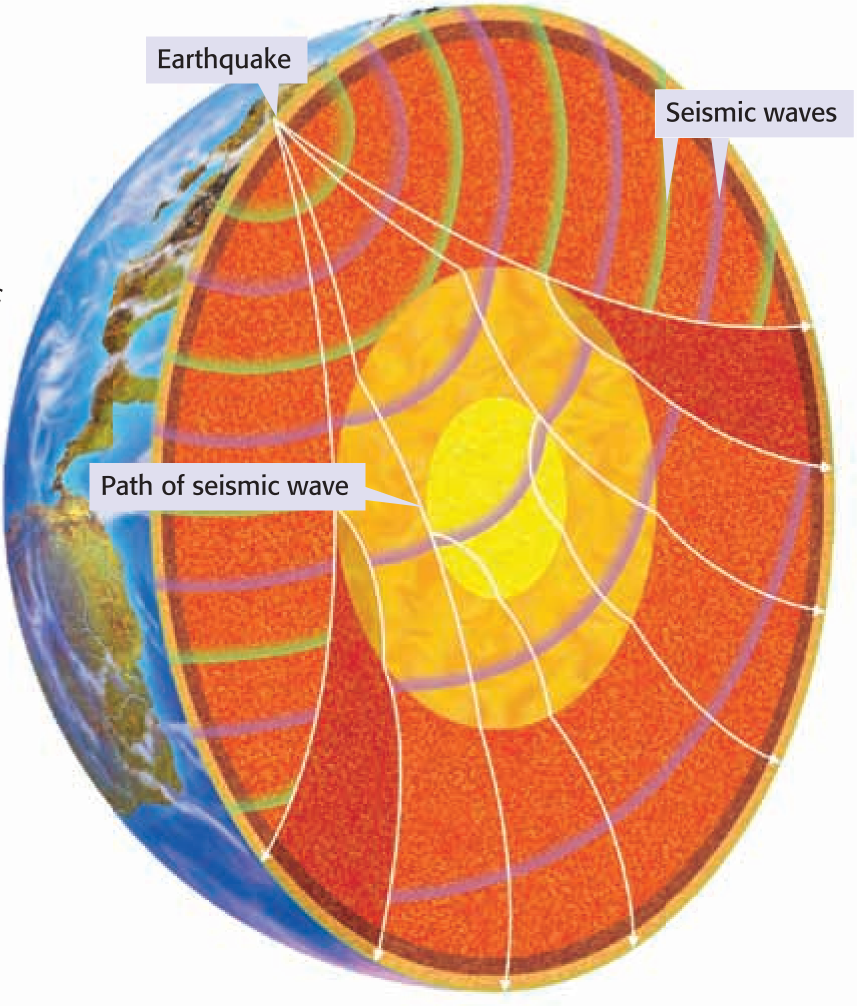


Figure 6 *By measuring changes in the speed of seismic waves that travel through Earth's interior, seismologists have learned that the Earth is made of different layers.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION Review

Summary

- The Earth is made up of three layers—the crust, the mantle, and the core—based on chemical composition. Less dense compounds make up the crust and mantle. Denser compounds make up the core.
- The Earth is made up of five main physical layers: the lithosphere, the asthenosphere, the mesosphere, the outer core, and the inner core.
- Tectonic plates are large pieces of the lithosphere that move around on the Earth's surface.
- The crust in some tectonic plates is mainly continental. Other plates have only oceanic crust. Still other plates include both continental and oceanic crust.
- Thick tectonic plates, such as those in which the crust is mainly continental, displace more asthenosphere than do thin plates, such as those in which the crust is mainly oceanic.
- Knowledge about the layers of the Earth comes from the study of seismic waves caused by earthquakes.

Using Key Terms

For each pair of terms, explain how the meanings of the terms differ.

1. *crust* and *mantle*
2. *lithosphere* and *asthenosphere*

Understanding Key Ideas

3. The part of the Earth that is molten is the
   a. crust.
   b. mantle.
   c. outer core.
   d. inner core.
4. The part of the Earth on which the tectonic plates move is the
   a. lithosphere.
   b. asthenosphere.
   c. mesosphere.
   d. crust.
5. Identify the layers of the Earth by their chemical composition.
6. Identify the layers of the Earth by their physical properties.
7. Describe a tectonic plate.
8. Explain how scientists know about the structure of the Earth's interior.

Interpreting Graphics

9. According to the wave speeds shown in the table below, which two physical layers of the Earth are densest?

Speed of Seismic Waves in Earth's Interior

Physical layer	Wave speed
Lithosphere	7 to 8 km/s
Asthenosphere	7 to 11 km/s
Mesosphere	11 to 13 km/s
Outer core	8 to 10 km/s
Inner core	11 to 12 km/s

Critical Thinking

10. **Making Comparisons** Explain the difference between the crust and the lithosphere.
11. **Analyzing Ideas** Why does a seismic wave travel faster through solid rock than through water?

SCILINKS® NSTA
Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org
Topic: Composition of the Earth; Structure of the Earth
SciLinks code: HSM0329; HSM1468

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 2

Restless Continents

Have you ever looked at a map of the world and noticed how the coastlines of continents on opposite sides of the oceans appear to fit together like the pieces of a puzzle? Is it just coincidence that the coastlines fit together well? Is it possible that the continents were actually together sometime in the past?

READING WARM-UP

Objectives

- Describe Wegener's hypothesis of continental drift.
- Explain how sea-floor spreading provides a way for continents to move.
- Describe how new oceanic lithosphere forms at mid-ocean ridges.
- Explain how magnetic reversals provide evidence for sea-floor spreading.

Terms to Learn

continental drift
sea-floor spreading

READING STRATEGY

Paired Summarizing Read this section silently. In pairs, take turns summarizing the material. Stop to discuss ideas that seem confusing.

Wegener's Continental Drift Hypothesis

One scientist who looked at the pieces of this puzzle was Alfred Wegener (VAY guh nuhr). In the early 1900s, he wrote about his hypothesis of *continental drift*. **Continental drift** is the hypothesis that states that the continents once formed a single landmass, broke up, and drifted to their present locations. This hypothesis seemed to explain a lot of puzzling observations, including the observation of how well continents fit together.

Continental drift also explained why fossils of the same plant and animal species are found on continents that are on different sides of the Atlantic Ocean. Many of these ancient species could not have crossed the Atlantic Ocean. As you can see in **Figure 1,** without continental drift, this pattern of fossils would be hard to explain. In addition to fossils, similar types of rock and evidence of the same ancient climatic conditions were found on several continents.

Reading Check **How did fossils provide evidence for Wegener's hypothesis of continental drift?** (*See the Appendix for answers to Reading Checks.*)

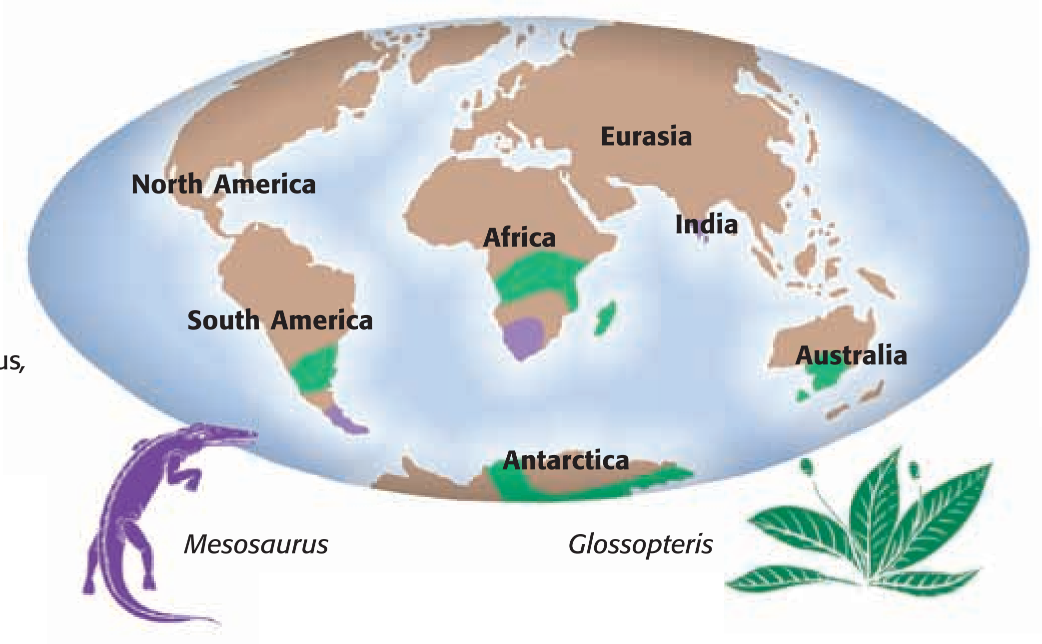
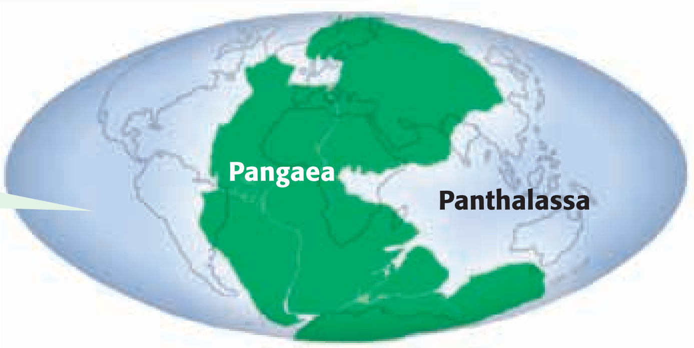


Figure 1 *Fossils of* Mesosaurus, *a small, aquatic reptile, and* Glossopteris, *an ancient plant species, have been found on several continents.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 2 The Drifting Continents

245 Million Years Ago
Pangaea existed when some of the earliest dinosaurs were roaming the Earth. The continent was surrounded by a sea called *Panthalassa*, which means “all sea.”



180 Million Years Ago
Gradually, Pangaea broke into two big pieces. The northern piece is called *Laurasia*. The southern piece is called *Gondwana*.

65 Million Years Ago
By the time the dinosaurs became extinct, Laurasia and Gondwana had split into smaller pieces.

The Breakup of Pangaea

Wegener made many observations before proposing his hypothesis of continental drift. He thought that all of the present continents were once joined in a single, huge continent. Wegener called this continent *Pangaea* (pan JEE uh), which is Greek for “all earth.” We now know from the hypothesis of plate tectonics that Pangaea existed about 245 million years ago. We also know that Pangaea further split into two huge continents—Laurasia and Gondwana—about 180 million years ago. As shown in **Figure 2,** these two continents split again and formed the continents we know today.

continental drift the hypothesis that states that the continents once formed a single landmass, broke up, and drifted to their present locations

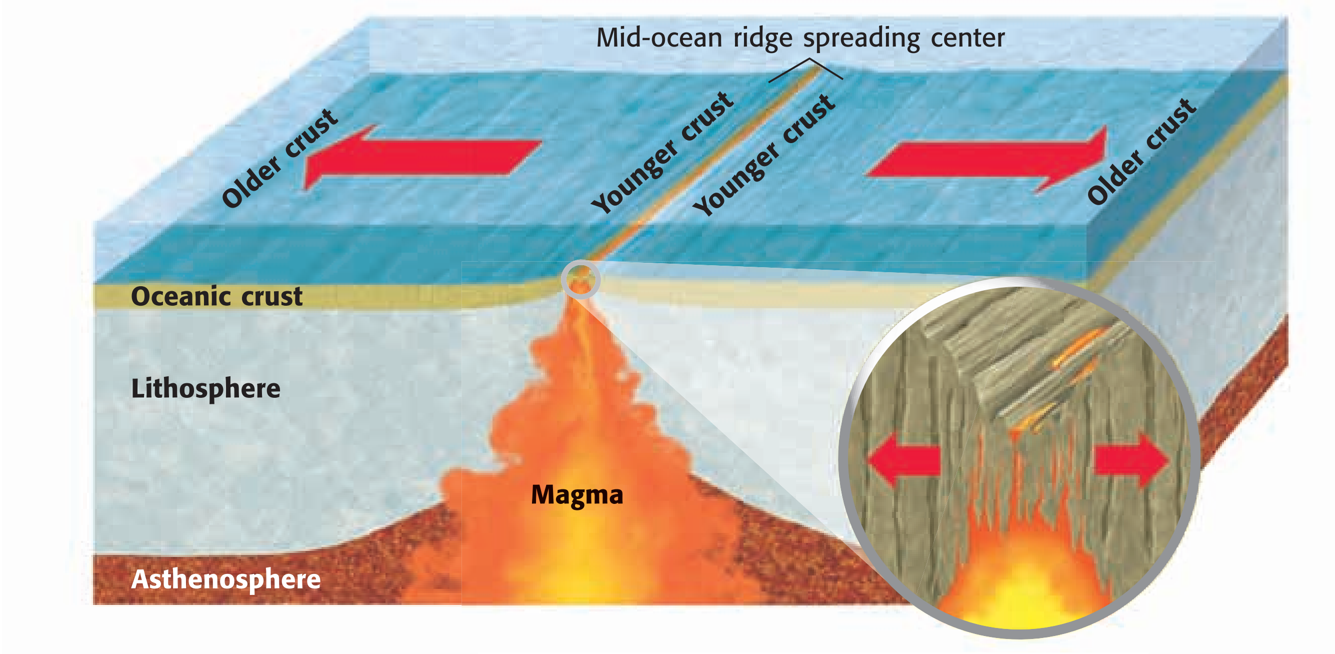
Sea-Floor Spreading

When Wegener put forth his hypothesis of continental drift, many scientists would not accept his hypothesis. From the calculated strength of the rocks, it did not seem possible for the crust to move in this way. During Wegener’s life, no one knew the answer. It wasn’t until many years later that evidence provided some clues to the forces that moved the continents.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 3 **Sea-Floor Spreading**

Sea-floor spreading creates new oceanic lithosphere at mid-ocean ridges.



sea-floor spreading the process by which new oceanic lithosphere forms as magma rises toward the surface and solidifies

Mid-Ocean Ridges and Sea-Floor Spreading

A chain of submerged mountains runs through the center of the Atlantic Ocean. The chain is part of a worldwide system of mid-ocean ridges. Mid-ocean ridges are underwater mountain chains that run through Earth's ocean basins.

Mid-ocean ridges are places where sea-floor spreading takes place. **Sea-floor spreading** is the process by which new oceanic lithosphere forms as magma rises toward the surface and solidifies. As the tectonic plates move away from each other, the sea floor spreads apart and magma fills in the gap. As this new crust forms, the older crust gets pushed away from the mid-ocean ridge. As **Figure 3** shows, the older crust is farther away from the mid-ocean ridge than the younger crust is.

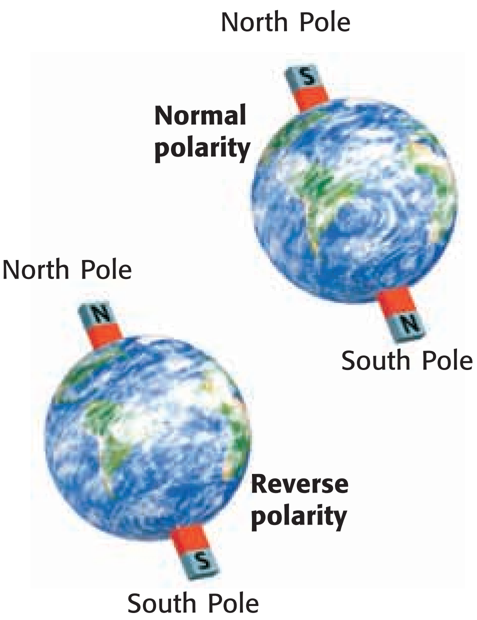


Figure 4 *The polarity of Earth's magnetic field changes over time.*

Evidence for Sea-Floor Spreading: Magnetic Reversals

Some of the most important evidence of sea-floor spreading comes from magnetic reversals recorded in the ocean floor. Throughout Earth's history, the north and south magnetic poles have changed places many times. When the poles change places, the polarity of Earth's magnetic poles changes, as shown in **Figure 4.** When Earth's magnetic poles change places, this change is called a *magnetic reversal*.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Magnetic Reversals and Sea-Floor Spreading

The molten rock at the mid-ocean ridges contains tiny grains of magnetic minerals. These mineral grains contain iron and are like compasses. They align with the magnetic field of the Earth. When the molten rock cools, the record of these tiny compasses remains in the rock. This record is then carried slowly away from the spreading center of the ridge as sea-floor spreading occurs.

As you can see in **Figure 5,** when the Earth's magnetic field reverses, the magnetic mineral grains align in the opposite direction. The new rock records the direction of the Earth's magnetic field. As the sea floor spreads away from a mid-ocean ridge, it carries with it a record of magnetic reversals. This record of magnetic reversals was the final proof that sea-floor spreading does occur.

Reading Check **How is a record of magnetic reversals recorded in molten rock at mid-ocean ridges?**

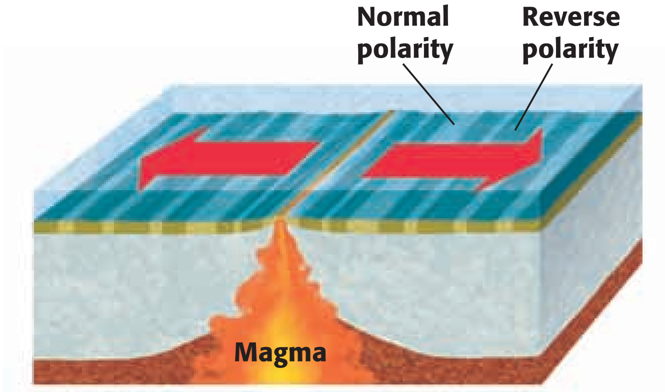


Figure 5 *Magnetic reversals in oceanic crust are shown as bands of light blue and dark blue oceanic crust. Light blue bands indicate normal polarity, and dark blue bands indicate reverse polarity.*

SECTION Review

Summary

- Wegener hypothesized that continents drift apart from one another and have done so in the past.
- The process by which new oceanic lithosphere forms at mid-ocean ridges is called sea-floor spreading.
- As tectonic plates separate, the sea floor spreads apart and magma fills in the gap.
- Magnetic reversals are recorded over time in oceanic crust.

Using Key Terms

1. In your own words, write a definition for each of the following terms: *continental drift* and *sea-floor spreading*.

Understanding Key Ideas

2. At mid-ocean ridges,
   a. the crust is older.
   b. sea-floor spreading occurs.
   c. oceanic lithosphere is destroyed.
   d. tectonic plates are colliding.
3. Explain how oceanic lithosphere forms at mid-ocean ridges.
4. What is magnetic reversal?

Math Skills

5. If a piece of sea floor has moved 50 km in 5 million years, what is the yearly rate of sea-floor motion?

Critical Thinking

6. **Identifying Relationships** Explain how magnetic reversals provide evidence for sea-floor spreading.
7. **Applying Concepts** Why do bands indicating magnetic reversals appear to be of similar width on both sides of a mid-ocean ridge?
8. **Applying Concepts** Why do you think that old rocks are rare on the ocean floor?

SCILINKS® NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Tectonic Plates
SciLinks code: HSM1497

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 3

The Theory of Plate Tectonics

READING WARM-UP

Objectives

- Describe the three types of tectonic plate boundaries.
- Describe the three forces thought to move tectonic plates.
- Explain how scientists measure the rate at which tectonic plates move.

Terms to Learn

plate tectonics
convergent boundary
divergent boundary
transform boundary

READING STRATEGY

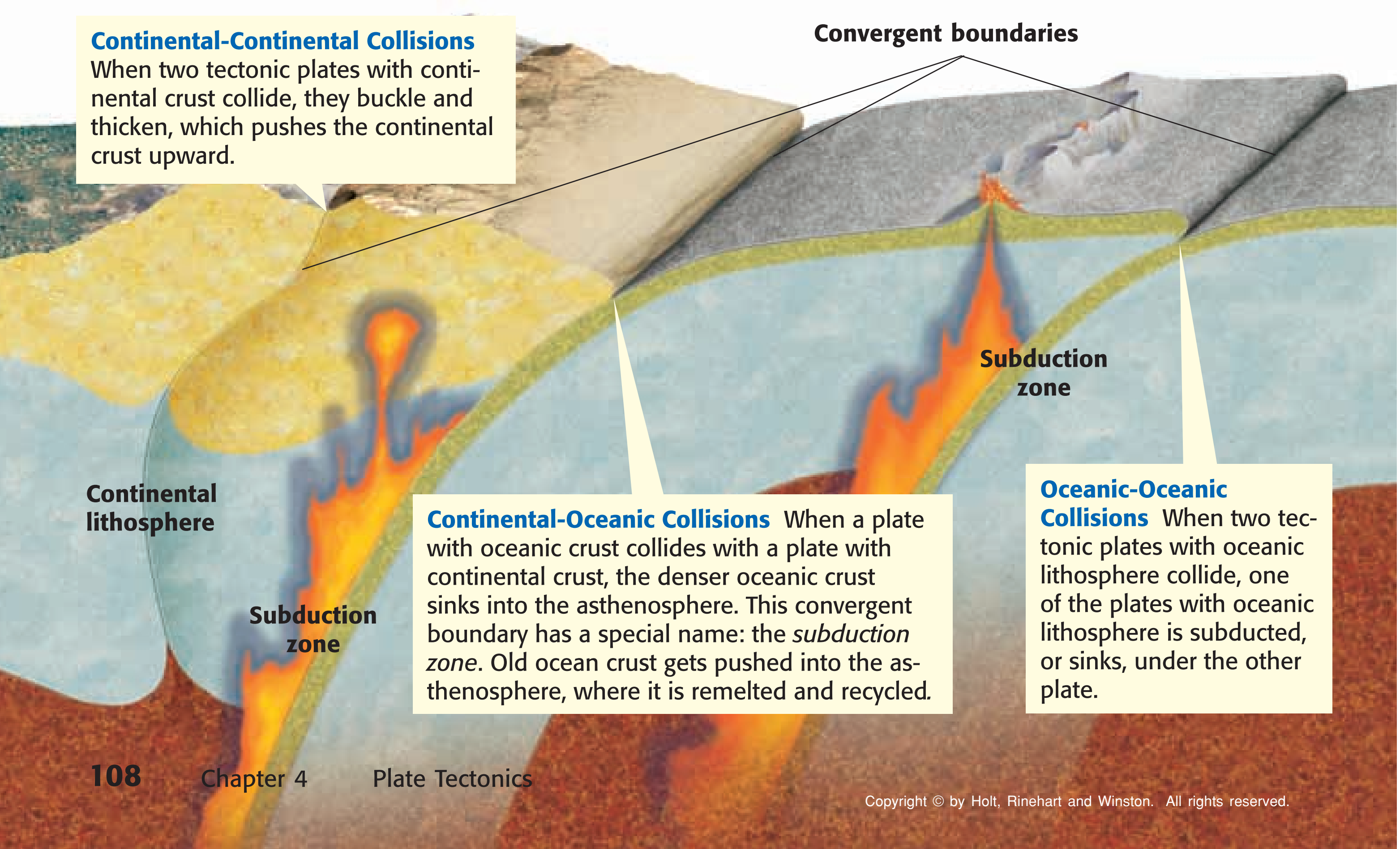
Brainstorming The key idea of this section is plate tectonics. Brainstorm words and phrases related to plate tectonics.

It takes an incredible amount of force to move a tectonic plate! But where does this force come from?

As scientists' understanding of mid-ocean ridges and magnetic reversals grew, scientists formed a theory to explain how tectonic plates move. **Plate tectonics** is the theory that the Earth's lithosphere is divided into tectonic plates that move around on top of the asthenosphere. In this section, you will learn what causes tectonic plates to move. But first you will learn about the different types of tectonic plate boundaries.

Tectonic Plate Boundaries

A boundary is a place where tectonic plates touch. All tectonic plates share boundaries with other tectonic plates. These boundaries are divided into three types: convergent, divergent, and transform. The type of boundary depends on how the tectonic plates move relative to one another. Tectonic plates can collide, separate, or slide past each other. Earthquakes can occur at all three types of plate boundaries. The figure below shows examples of tectonic plate boundaries.



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Convergent Boundaries

When two tectonic plates collide, the boundary between them is a **convergent boundary.** What happens at a convergent boundary depends on the kind of crust at the leading edge of each tectonic plate. The three types of convergent boundaries are continental-continental boundaries, continental-oceanic boundaries, and oceanic-oceanic boundaries.

Divergent Boundaries

When two tectonic plates separate, the boundary between them is called a **divergent boundary.** New sea floor forms at divergent boundaries. Mid-ocean ridges are the most common type of divergent boundary.

Transform Boundaries

When two tectonic plates slide past each other horizontally, the boundary between them is a **transform boundary.** The San Andreas Fault in California is a good example of a transform boundary. This fault marks the place where the Pacific and North American plates are sliding past each other.

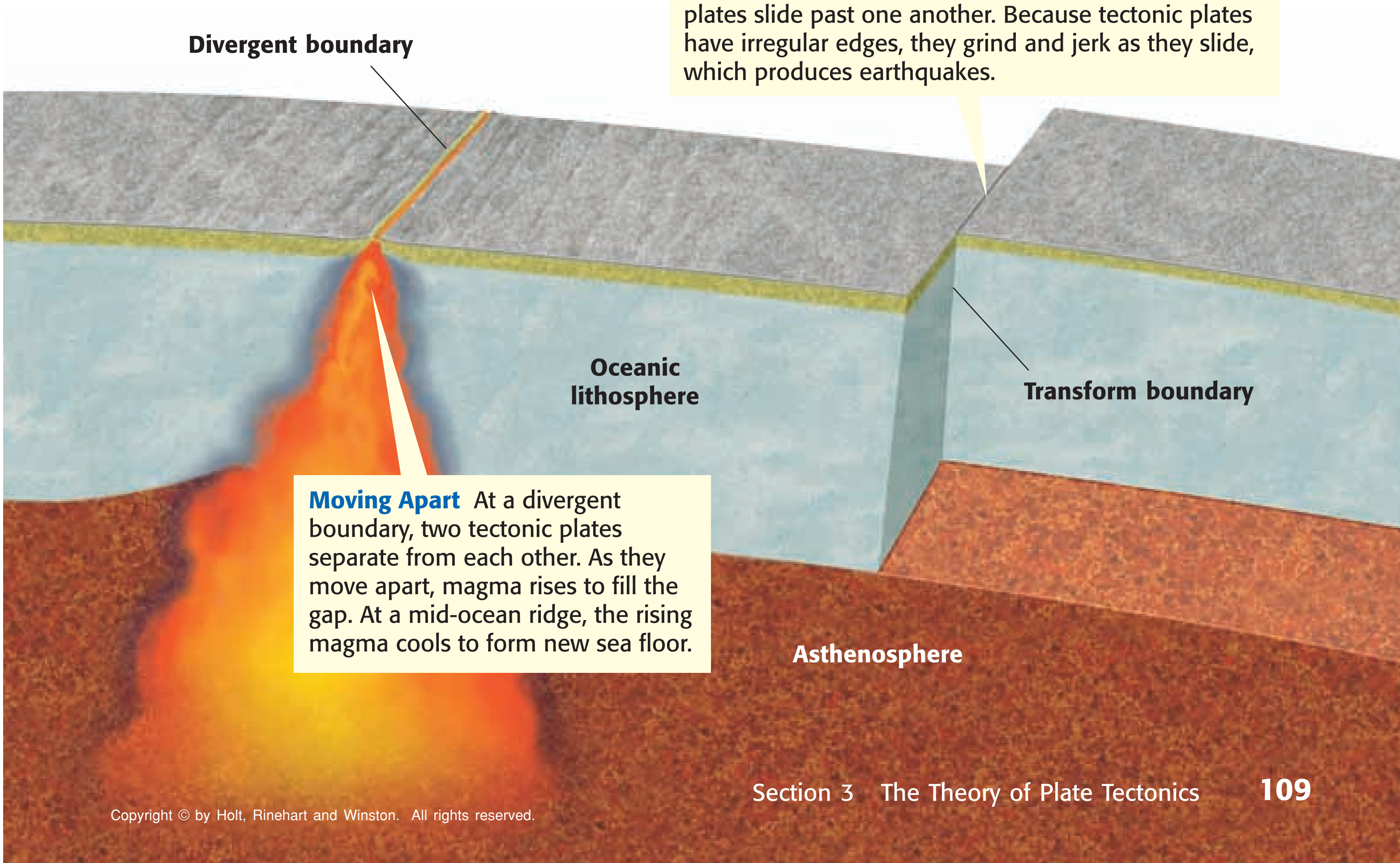
Reading Check **Define the term *transform boundary*.** (*See the Appendix for answers to Reading Checks.*)

plate tectonics the theory that explains how large pieces of the Earth's outermost layer, called *tectonic plates,* move and change shape

convergent boundary the boundary formed by the collision of two lithospheric plates

divergent boundary the boundary between two tectonic plates that are moving away from each other

transform boundary the boundary between tectonic plates that are sliding past each other horizontally



Sliding Past At a transform boundary, two tectonic plates slide past one another. Because tectonic plates have irregular edges, they grind and jerk as they slide, which produces earthquakes.

Moving Apart At a divergent boundary, two tectonic plates separate from each other. As they move apart, magma rises to fill the gap. At a mid-ocean ridge, the rising magma cools to form new sea floor.

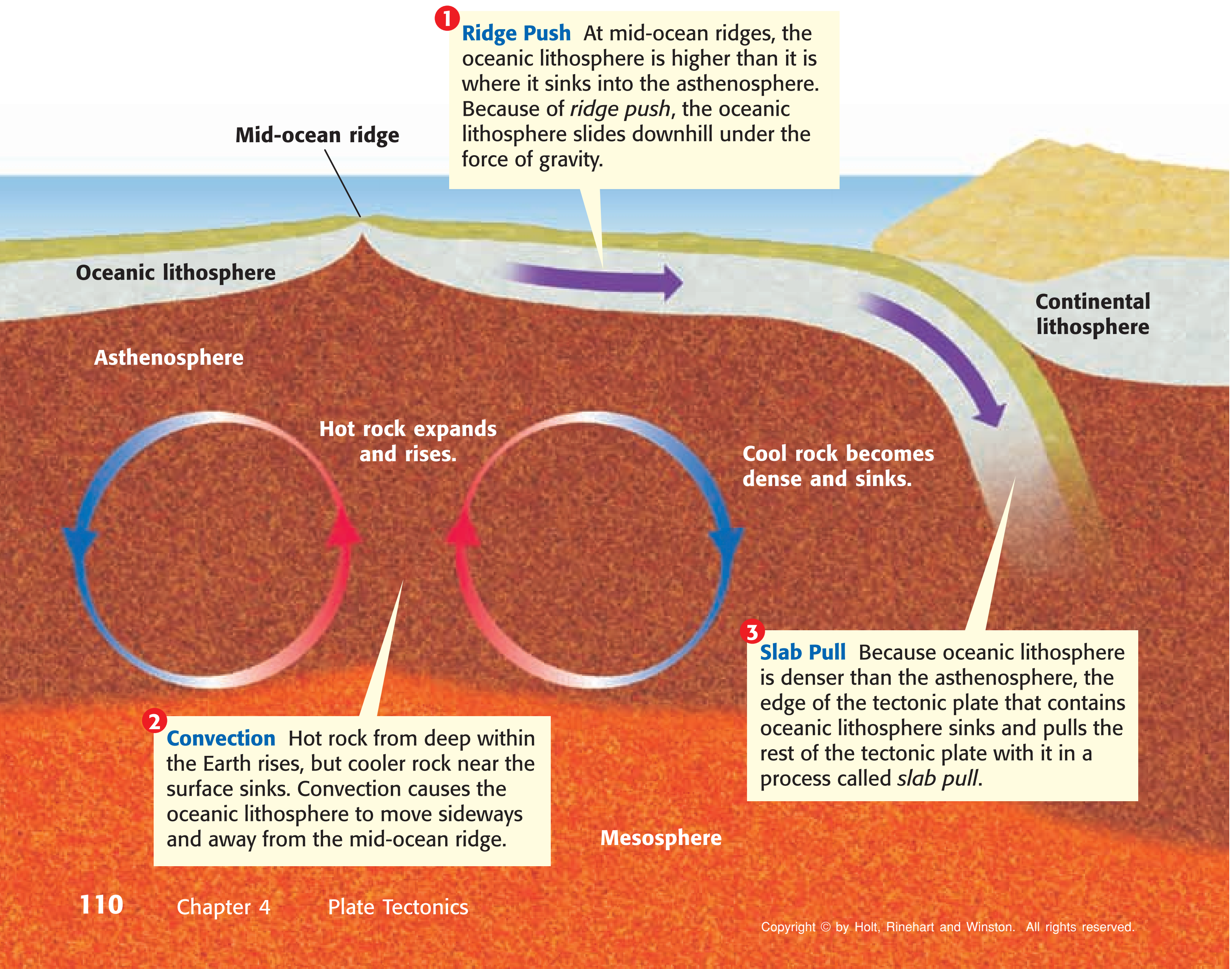
Copyright © by Holt, Rinehart and Winston. All rights reserved.

Possible Causes of Tectonic Plate Motion

You have learned that plate tectonics is the theory that the lithosphere is divided into tectonic plates that move around on top of the asthenosphere. What causes the motion of tectonic plates? Remember that the solid rock of the asthenosphere flows very slowly. This movement occurs because of changes in density within the asthenosphere. These density changes are caused by the outward flow of thermal energy from deep within the Earth. When rock is heated, it expands, becomes less dense, and tends to rise to the surface of the Earth. As the rock gets near the surface, the rock cools, becomes more dense, and tends to sink. **Figure 1** shows three possible causes of tectonic plate motion.

Reading Check **What causes changes in density in the asthenosphere?**

Figure 1 **Three Possible Driving Forces of Plate Tectonics**



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Tracking Tectonic Plate Motion

How fast do tectonic plates move? The answer to this question depends on many factors, such as the type and shape of the tectonic plate and the way that the tectonic plate interacts with the tectonic plates that surround it. Tectonic plate movements are so slow and gradual that you can't see or feel them—the movement is measured in centimeters per year.

The Global Positioning System

Scientists use a system of satellites called the *global positioning system* (GPS), shown in **Figure 2,** to measure the rate of tectonic plate movement. Radio signals are continuously beamed from satellites to GPS ground stations, which record the exact distance between the satellites and the ground station. Over time, these distances change slightly. By recording the time it takes for the GPS ground stations to move a given distance, scientists can measure the speed at which each tectonic plate moves.

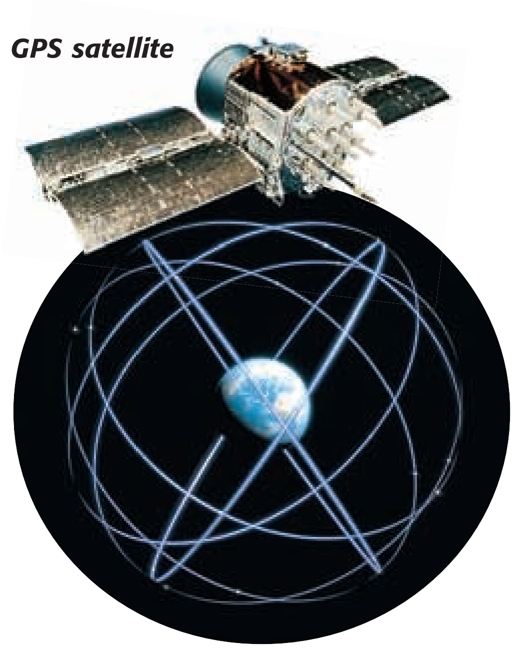


Figure 2 *The image above shows the orbits of the GPS satellites.*

SECTION Review

Summary

- Boundaries between tectonic plates are classified as convergent, divergent, or transform.
- Ridge push, convection, and slab pull are three possible driving forces of plate tectonics.
- Scientists use data from a system of satellites called the global positioning system to measure the rate of motion of tectonic plates.

Using Key Terms

1. In your own words, write a definition for the term *plate tectonics*.

Understanding Key Ideas

2. The speed a tectonic plate moves per year is best measured in
   a. kilometers per year.
   b. centimeters per year.
   c. meters per year.
   d. millimeters per year.
3. Briefly describe three possible driving forces of tectonic plate movement.
4. Explain how scientists use GPS to measure the rate of tectonic plate movement.

Math Skills

5. If an orbiting satellite has a diameter of 60 cm, what is the total surface area of the satellite? (Hint: *surface area* = $4\pi r^2$)

Critical Thinking

6. **Identifying Relationships** When convection takes place in the mantle, why does cool rock material sink and warm rock material rise?
7. **Analyzing Processes** Why does oceanic crust sink beneath continental crust at convergent boundaries?

SCILINKS. NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Plate Tectonics
SciLinks code: HSM1171

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 4

Deforming the Earth's Crust

READING WARM-UP

Objectives

- Describe two types of stress that deform rocks.
- Describe three major types of folds.
- Explain the differences between the three major types of faults.
- Identify the most common types of mountains.
- Explain the difference between uplift and subsidence.

Terms to Learn

compression	fault
tension	uplift
folding	subsidence

READING STRATEGY

Discussion Read this section silently. Write down questions that you have about this section. Discuss your questions in a small group.

Have you ever tried to bend something, only to have it break? Take long, uncooked pieces of spaghetti, and bend them very slowly but only a little. Now, bend them again, but this time, bend them much farther and faster. What happened?

How can a material bend at one time and break at another time? The answer is that the stress you put on the material was different each time. *Stress* is the amount of force per unit area on a given material. The same principle applies to the rocks in the Earth's crust. Different things happen to rock when different types of stress are applied.

Deformation

The process by which the shape of a rock changes because of stress is called *deformation*. In the example above, the spaghetti deformed in two different ways—by bending and by breaking. **Figure 1** illustrates this concept. The same thing happens in rock layers. Rock layers bend when stress is placed on them. But when enough stress is placed on rocks, they can reach their elastic limit and break.

Compression and Tension

The type of stress that occurs when an object is squeezed, such as when two tectonic plates collide, is called **compression.** When compression occurs at a convergent boundary, large mountain ranges can form.

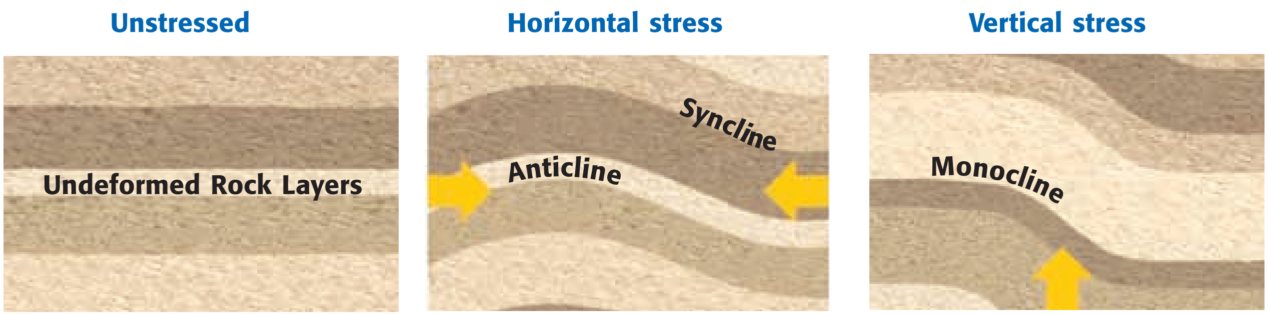
Another form of stress is *tension*. **Tension** is stress that occurs when forces act to stretch an object. As you might guess, tension occurs at divergent plate boundaries, such as mid-ocean ridges, when two tectonic plates pull away from each other.

✓ *Reading Check* **How do the forces of plate tectonics cause rock to deform?** (*See the Appendix for answers to Reading Checks.*)

Figure 1 *When a small amount of stress is placed on uncooked spaghetti, the spaghetti bends. Additional stress causes the spaghetti to break.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 2 **Folding: When Rock Layers Bend Because of Stress**



Folding

The bending of rock layers because of stress in the Earth's crust is called **folding.** Scientists assume that all rock layers started as horizontal layers. So, when scientists see a fold, they know that deformation has taken place.

compression stress that occurs when forces act to squeeze an object

tension stress that occurs when forces act to stretch an object

folding the bending of rock layers due to stress

Types of Folds

Depending on how the rock layers deform, different types of folds are made. **Figure 2** shows the two most common types of folds—*anticlines*, or upward-arching folds, and *synclines,* downward, troughlike folds. Another type of fold is a *monocline*. In a monocline, rock layers are folded so that both ends of the fold are horizontal. Imagine taking a stack of paper and laying it on a table. Think of the sheets of paper as different rock layers. Now put a book under one end of the stack. You can see that both ends of the sheets are horizontal, but all of the sheets are bent in the middle.

Folds can be large or small. The largest folds are measured in kilometers. Other folds are also obvious but are much smaller. These small folds can be measured in centimeters. **Figure 3** shows examples of large and small folds.

Figure 3 *The large photo shows mountain-sized folds in the Rocky Mountains. The small photo shows a rock that has folds smaller than a penknife.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

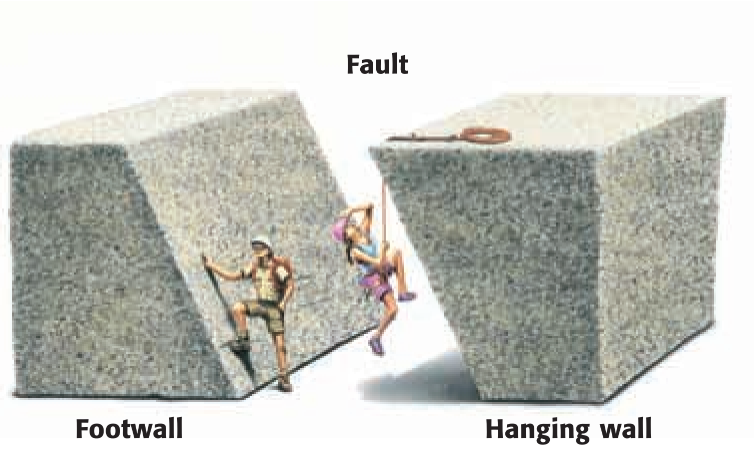


Figure 4 *The position of a fault block determines whether it is a hanging wall or a footwall.*

Faulting

Some rock layers break when stress is applied to them. The surface along which rocks break and slide past each other is called a **fault.** The blocks of crust on each side of the fault are called *fault blocks*.

When a fault is not vertical, understanding the difference between its two sides—the *hanging wall* and the *footwall*—is useful. **Figure 4** shows the difference between a hanging wall and a footwall. Two main types of faults can form. The type of fault that forms depends on how the hanging wall and footwall move in relationship to each other.

Normal Faults

A *normal fault* is shown in **Figure 5.** When a normal fault moves, it causes the hanging wall to move down relative to the footwall. Normal faults usually occur when tectonic forces cause tension that pulls rocks apart.

fault a break in a body of rock along which one block slides relative to another

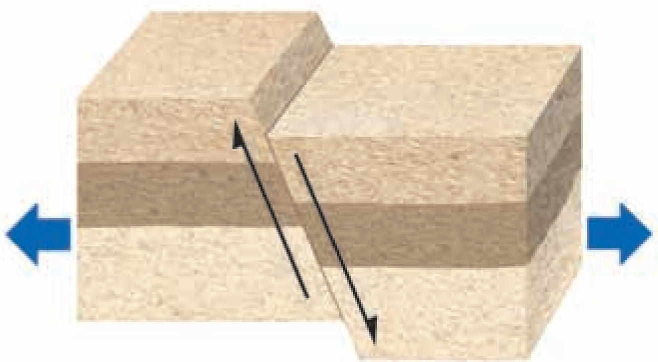
Reverse Faults

A *reverse fault* is shown in **Figure 5.** When a reverse fault moves, it causes the hanging wall to move up relative to the footwall. This movement is the reverse of a normal fault. Reverse faults usually happen when tectonic forces cause compression that pushes rocks together.

Reading Check **How does the hanging wall in a normal fault move in relation to a reverse fault?**

Figure 5 **Normal and Reverse Faults**

Normal Fault When rocks are pulled apart because of tension, normal faults often form.



Reverse Fault When rocks are pushed together by compression, reverse faults often form.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

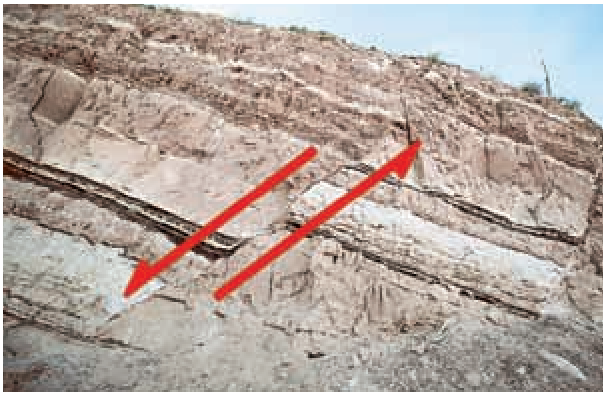


Figure 6 *The photo at left is a normal fault. The photo at right is a reverse fault.*

Telling the Difference Between Faults

It's easy to tell the difference between a normal fault and a reverse fault in drawings with arrows. But what types of faults are shown in **Figure 6**? You can certainly see the faults, but which one is a normal fault, and which one is a reverse fault? In the top left photo in **Figure 6,** one side has obviously moved relative to the other side. You can tell this fault is a normal fault by looking at the order of sedimentary rock layers. If you compare the two dark layers near the surface, you can see that the hanging wall has moved down relative to the footwall.

Strike-Slip Faults

A third major type of fault is called a *strike-slip fault*. An illustration of a strike-slip fault is shown in **Figure 7.** *Strike-slip faults* form when opposing forces cause rock to break and move horizontally. If you were standing on one side of a strike-slip fault looking across the fault when it moved, the ground on the other side would appear to move to your left or right. The San Andreas Fault in California is a spectacular example of a strike-slip fault.

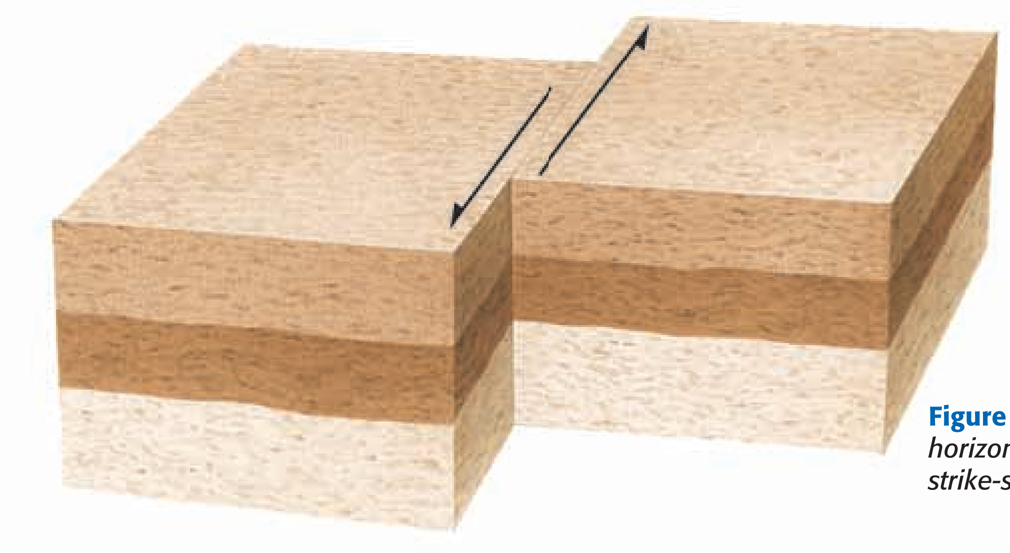


Figure 7 *When rocks are moved horizontally by opposing forces, strike-slip faults often form.*

Quick Lab

Modeling Strike-Slip Faults

1. Use **modeling clay** to construct a box that is 6 in. × 6 in. × 4 in. Use different colors of clay to represent different horizontal layers.
2. Using **scissors,** cut the box down the middle. Place **two 4 in. × 6 in. index cards** inside the cut so that the two sides of the box slide freely.
3. Using gentle pressure, slide the two sides horizontally past one another.
4. How does this model illustrate the motion that occurs along a strike-slip fault?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

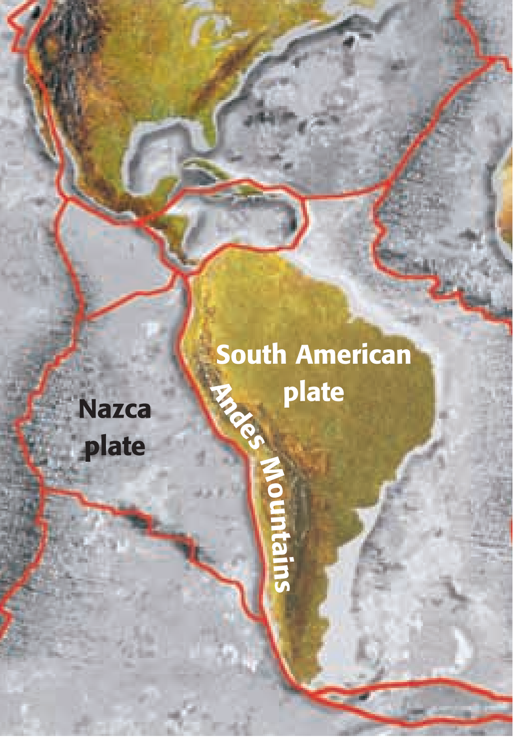


Figure 8 *The Andes Mountains formed on the edge of the South American plate where it converges with the Nazca plate.*

Plate Tectonics and Mountain Building

You have just learned about several ways the Earth's crust changes because of the forces of plate tectonics. When tectonic plates collide, land features that start as folds and faults can eventually become large mountain ranges. Mountains exist because tectonic plates are continually moving around and colliding with one another. As shown in **Figure 8,** the Andes Mountains formed above the subduction zone where two tectonic plates converge.

When tectonic plates undergo compression or tension, they can form mountains in several ways. Take a look at three of the most common types of mountains—folded mountains, fault-block mountains, and volcanic mountains.

Folded Mountains

The highest mountain ranges in the world are made up of folded mountains. These ranges form at convergent boundaries where continents have collided. *Folded mountains* form when rock layers are squeezed together and pushed upward. If you place a pile of paper on a table and push on opposite edges of the pile, you will see how folded mountains form.

An example of a folded mountain range that formed at a convergent boundary is shown in **Figure 9.** About 390 million years ago, the Appalachian Mountains formed when the landmasses that are now North America and Africa collided. Other examples of mountain ranges that consist of very large and complex folds are the Alps in central Europe, the Ural Mountains in Russia, and the Himalayas in Asia.

Reading Check **Explain how folded mountains form.**

Figure 9 *The Appalachian Mountains were once as tall as the Himalaya Mountains but have been worn down by hundreds of millions of years of weathering and erosion.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

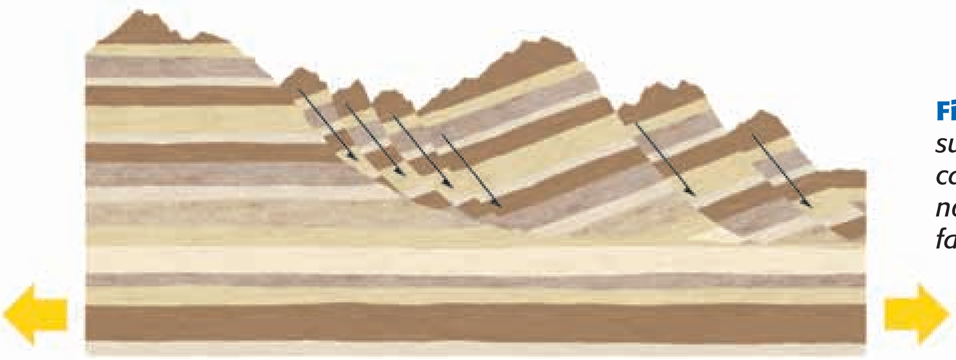


Figure 10 *When the crust is subjected to tension, the rock can break along a series of normal faults, which creates fault-block mountains.*

Fault-Block Mountains

When tectonic forces put enough tension on the Earth's crust, a large number of normal faults can result. *Fault-block mountains* form when this tension causes large blocks of the Earth's crust to drop down relative to other blocks. **Figure 10** shows one way that fault-block mountains form.

When sedimentary rock layers are tilted up by faulting, they can produce mountains that have sharp, jagged peaks. As shown in **Figure 11,** the Tetons in western Wyoming are a spectacular example of fault-block mountains.

Volcanic Mountains

Most of the world's major volcanic mountains are located at convergent boundaries where oceanic crust sinks into the asthenosphere at subduction zones. The rock that is melted in subduction zones forms magma, which rises to the Earth's surface and erupts to form *volcanic mountains*. Volcanic mountains can also form under the sea. Sometimes these mountains can rise above the ocean surface to become islands. The majority of tectonically active volcanic mountains on the Earth have formed around the tectonically active rim of the Pacific Ocean. The rim has become known as the *Ring of Fire*.

CONNECTION TO Social Studies

WRITING SKILL **The Naming of the Appalachian Mountains** How did the Appalachian Mountains get their name? It is believed that the Appalachian Mountains were named by Spanish explorers in North America during the 16th century. It is thought that the name was taken from a Native American tribe called *Appalachee,* who lived in northern Florida. Research other geological features in the United States, including mountains and rivers, whose names are of Native American origin. Write the results of your research in a short essay.

Figure 11 *The Tetons formed as a result of tectonic forces that stretched the Earth's crust and caused it to break in a series of normal faults.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Uplift and Subsidence

Vertical movements in the crust are divided into two types—uplift and subsidence. The rising of regions of Earth's crust to higher elevations is called **uplift.** Rocks that are uplifted may or may not be highly deformed. The sinking of regions of Earth's crust to lower elevations is known as **subsidence** (suhb SIED'ns). Unlike some uplifted rocks, rocks that subside do not undergo much deformation.

INTERNET ACTIVITY

For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HZ5TECW.**

Uplifting of Depressed Rocks

The formation of mountains is one type of uplift. Uplift can also occur when large areas of land rise without deforming. One way areas rise without deforming is a process known as *rebound*. When the crust rebounds, it slowly springs back to its previous elevation. Uplift often happens when a weight is removed from the crust.

uplift the rising of regions of the Earth's crust to higher elevations

subsidence the sinking of regions of the Earth's crust to lower elevations

Subsidence of Cooler Rocks

Rocks that are hot take up more space than cooler rocks. For example, the lithosphere is relatively hot at mid-ocean ridges. The farther the lithosphere is from the ridge, the cooler and denser the lithosphere becomes. Because the oceanic lithosphere now takes up less volume, the ocean floor subsides.

Tectonic Letdown

Subsidence can also occur when the lithosphere becomes stretched in rift zones. A *rift zone* is a set of deep cracks that forms between two tectonic plates that are pulling away from each other. As tectonic plates pull apart, stress between the plates causes a series of faults to form along the rift zone. As shown in **Figure 12,** the blocks of crust in the center of the rift zone subside.

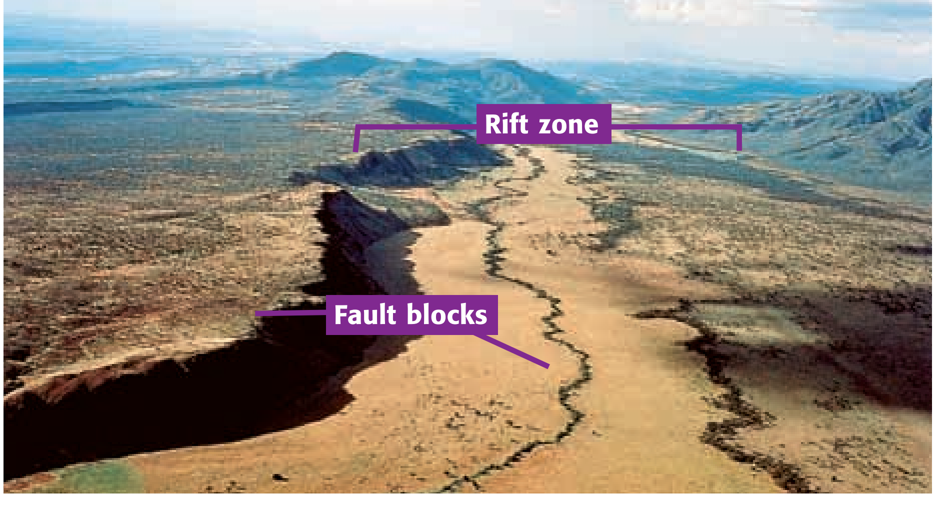


Figure 12 *The East African Rift, from Ethiopia to Kenya, is part of a divergent boundary, but you can see how the crust has subsided relative to the blocks at the edge of the rift zone.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION Review

Summary

- Compression and tension are two forces of plate tectonics that can cause rock to deform.
- Folding occurs when rock layers bend because of stress.
- Faulting occurs when rock layers break because of stress and then move on either side of the break.
- Mountains are classified as either folded, fault-block, or volcanic depending on how they form.
- Mountain building is caused by the movement of tectonic plates. Folded mountains and volcanic mountains form at convergent boundaries. Fault-block mountains form at divergent boundaries.
- Uplift and subsidence are the two types of vertical movement in the Earth's crust. Uplift occurs when regions of the crust rise to higher elevations. Subsidence occurs when regions of the crust sink to lower elevations.

Using Key Terms

For each pair of key terms, explain how the meanings of the terms differ.

1. *compression* and *tension*
2. *uplift* and *subsidence*

Understanding Key Ideas

3. The type of fault in which the hanging wall moves up relative to the footwall is called a
   a. strike-slip fault.
   b. fault-block fault.
   c. normal fault.
   d. reverse fault.
4. Describe three types of folds.
5. Describe three types of faults.
6. Identify the most common types of mountains.
7. What is rebound?
8. What are rift zones, and how do they form?

Critical Thinking

9. **Predicting Consequences** If a fault occurs in an area where rock layers have been folded, which type of fault is it likely to be? Why?
10. **Identifying Relationships** Would you expect to see a folded mountain range at a mid-ocean ridge? Explain your answer.

Interpreting Graphics

Use the diagram below to answer the questions that follow.

11. What type of fault is shown in the diagram?
12. At what kind of tectonic boundary would you most likely find this fault?

SCILINKS. NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Faults; Mountain Building
SciLinks code: HSM0566; HSM0999

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Using Scientific Methods

Model-Making Lab

Convection Connection

Some scientists think that convection currents within the Earth's mantle cause tectonic plates to move. Because these convection currents cannot be observed directly, scientists use models to simulate the process. In this activity, you will make your own model to simulate tectonic plate movement.

OBJECTIVES

Model convection currents to simulate plate tectonic movement.

Draw conclusions about the role of convection in plate tectonics.

MATERIALS

- craft sticks (2)
- food coloring
- gloves, heat-resistant
- hot plates, small (2)
- pan, aluminum, rectangular
- pencil
- ruler, metric
- thermometers (3)
- water, cold
- wooden blocks

SAFETY

Ask a Question

1. How can I make a model of convection currents in the Earth's mantle?

Form a Hypothesis

2. Turn the question above into a statement in which you give your best guess about what factors will have the greatest effect on your convection model.

Test the Hypothesis

3. Place two hot plates side by side in the center of your lab table. Be sure that they are away from the edge of the table.
4. Place the pan on top of the hot plates. Slide the wooden blocks under the pan to support the ends. Make sure that the pan is level and secure.
5. Fill the pan with cold water. The water should be at least 4 cm deep. Turn on the hot plates, and put on your gloves.
6. After a minute or two, tiny bubbles will begin to rise in the water above the hot plates. Gently place two craft sticks on the water's surface.
7. Use the pencil to align the sticks parallel to the short ends of the pan. The sticks should be about 3 cm apart and near the center of the pan.
8. As soon as the sticks begin to move, place a drop of food coloring in the center of the pan. Observe what happens to the food coloring.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

9 With the help of a partner, hold one thermometer bulb just under the water at the center of the pan. Hold the other two thermometers just under the water near the ends of the pan. Record the temperatures.

10 When you are finished, turn off the hot plates. After the water has cooled, carefully empty the water into a sink.

Analyze the Results

1 **Explaining Events** Based on your observations of the motion of the food coloring, how does the temperature of the water affect the direction in which the craft sticks move?

Draw Conclusions

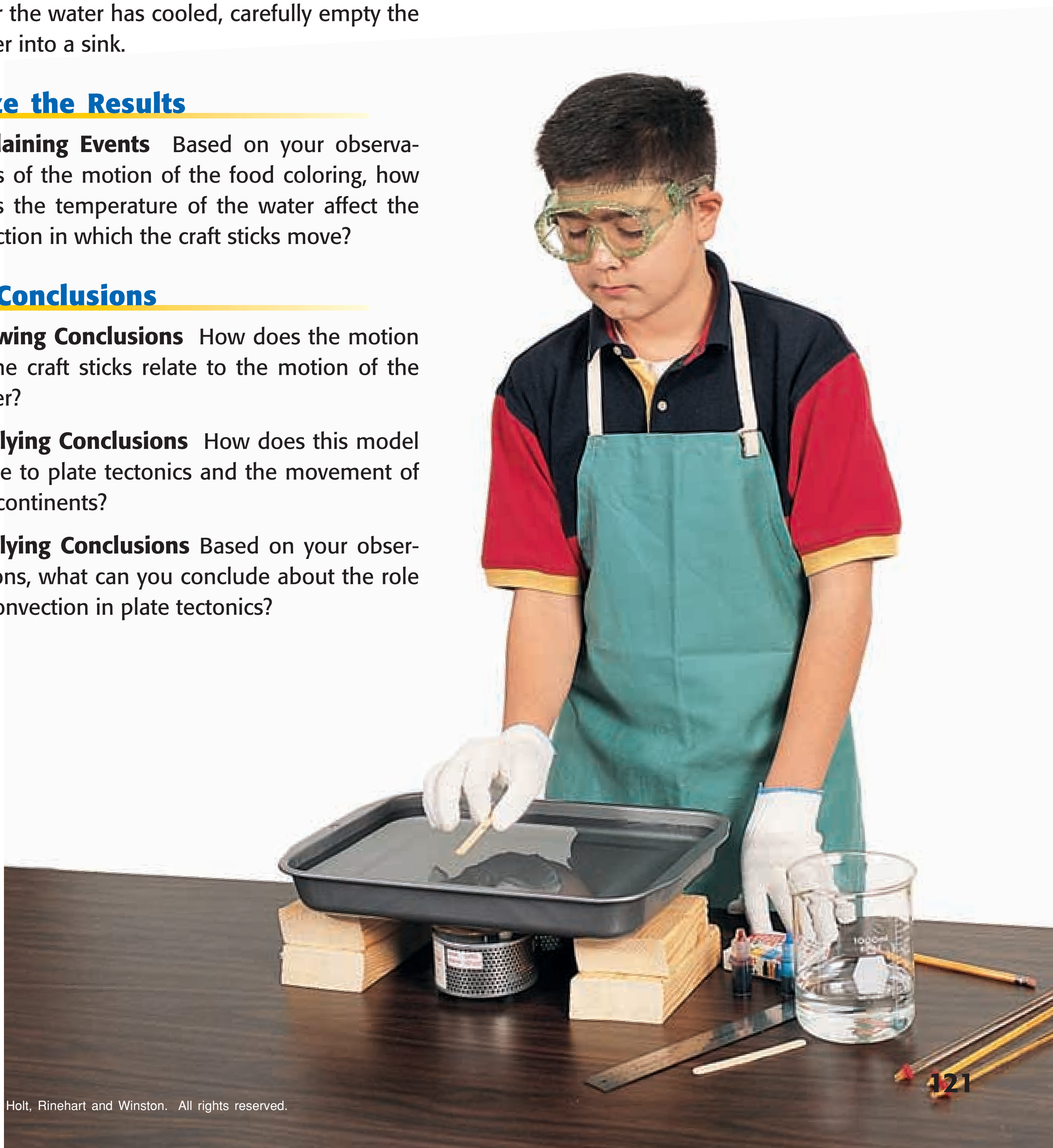
2 **Drawing Conclusions** How does the motion of the craft sticks relate to the motion of the water?

3 **Applying Conclusions** How does this model relate to plate tectonics and the movement of the continents?

4 **Applying Conclusions** Based on your observations, what can you conclude about the role of convection in plate tectonics?

Applying Your Data

Suggest a substance other than water that might be used to model convection in the mantle. Consider using a substance that flows more slowly than water.



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Chapter Review

USING KEY TERMS

1 Use the following terms in the same sentence: *crust, mantle,* and *core*.

Complete each of the following sentences by choosing the correct term from the word bank.

asthenosphere	uplift
tension	continental drift

2 The hypothesis that continents can drift apart and have done so in the past is known as ___.

3 The ___ is the soft layer of the mantle on which the tectonic plates move.

4 ___ is stress that occurs when forces act to stretch an object.

5 The rising of regions of the Earth's crust to higher elevations is called ___.

UNDERSTANDING KEY IDEAS

Multiple Choice

6 The strong, lower part of the mantle is a physical layer called the

a. lithosphere.
b. mesosphere.
c. asthenosphere.
d. outer core.

7 The type of tectonic plate boundary that forms from a collision between two tectonic plates is a

a. divergent plate boundary.
b. transform plate boundary.
c. convergent plate boundary.
d. normal plate boundary.

8 The bending of rock layers due to stress in the Earth's crust is known as

a. uplift.
b. folding.
c. faulting.
d. subsidence.

9 The type of fault in which the hanging wall moves up relative to the footwall is called a

a. strike-slip fault.
b. fault-block fault.
c. normal fault.
d. reverse fault.

10 The type of mountain that forms when rock layers are squeezed together and pushed upward is the

a. folded mountain.
b. fault-block mountain.
c. volcanic mountain.
d. strike-slip mountain.

11 Scientists' knowledge of the Earth's interior has come primarily from

a. studying magnetic reversals in oceanic crust.
b. using a system of satellites called the *global positioning system*.
c. studying seismic waves generated by earthquakes.
d. studying the pattern of fossils on different continents.

Short Answer

12 Explain how scientists use seismic waves to map the Earth's interior.

13 How do magnetic reversals provide evidence of sea-floor spreading?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

14. Explain how sea-floor spreading provides a way for continents to move.

15. Describe two types of stress that deform rock.

16. What is the global positioning system (GPS), and how does GPS allow scientists to measure the rate of motion of tectonic plates?

CRITICAL THINKING

17. **Concept Mapping** Use the following terms to create a concept map: *sea-floor spreading, convergent boundary, divergent boundary, subduction zone, transform boundary,* and *tectonic plates*.

18. **Applying Concepts** Why does oceanic lithosphere sink at subduction zones but not at mid-ocean ridges?

19. **Identifying Relationships** New tectonic material continually forms at divergent boundaries. Tectonic plate material is also continually destroyed in subduction zones at convergent boundaries. Do you think that the total amount of lithosphere formed on the Earth is about equal to the amount destroyed? Why?

20. **Applying Concepts** Folded mountains usually form at the edge of a tectonic plate. How can you explain folded mountain ranges located in the middle of a tectonic plate?

INTERPRETING GRAPHICS

Imagine that you could travel to the center of the Earth. Use the diagram below to answer the questions that follow.

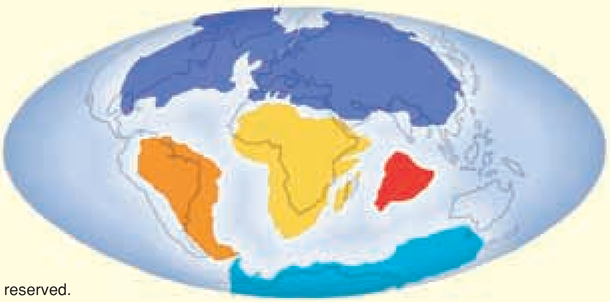
Composition	Structure
Crust (50 km)	Lithosphere (150 km)
Mantle (2,900 km)	Asthenosphere (250 km)
	Mesosphere (2,550 km)
Core (3,430 km)	Outer core (2,200 km)
	Inner core (1,228 km)

21. How far beneath the Earth's surface would you have to go before you were no longer passing through rock that had the composition of granite?

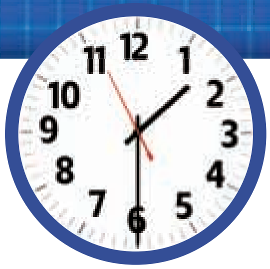
22. How far beneath the Earth's surface would you have to go to find liquid material in the Earth's core?

23. At what depth would you find mantle material but still be within the lithosphere?

24. How far beneath the Earth's surface would you have to go to find solid iron and nickel in the Earth's core?



Copyright © by Holt, Rinehart and Winston. All rights reserved.



Standardized Test Preparation

READING

Read each of the passages below. Then, answer the questions that follow each passage.

Passage 1 The Deep Sea Drilling Project was a program to retrieve and research rocks below the ocean to test the hypothesis of sea-floor spreading. For 15 years, scientists studying sea-floor spreading conducted research aboard the ship *Glomar Challenger*. Holes were drilled in the sea floor from the ship. Long, cylindrical lengths of rock, called *cores,* were obtained from the drill holes. By examining fossils in the cores, scientists discovered that rock closest to mid-ocean ridges was the youngest. The farther from the ridge the holes were drilled, the older the rock in the cores was. This evidence supported the idea that sea-floor spreading creates new lithosphere at mid-ocean ridges.

1. In the passage, what does *conducted* mean?

- **A** directed
- **B** led
- **C** carried on
- **D** guided

2. Why were cores drilled in the sea floor from the *Glomar Challenger*?

- **F** to determine the depth of the crust
- **G** to find minerals in the sea-floor rock
- **H** to examine fossils in the sea-floor rock
- **I** to find oil and gas in the sea-floor rock

3. Which of the following statements is a fact according to the passage?

- **A** Rock closest to mid-ocean ridges is older than rock at a distance from mid-ocean ridges.
- **B** One purpose of scientific research on the *Glomar Challenger* was to gather evidence for sea-floor spreading.
- **C** Fossils examined by scientists came directly from the sea floor.
- **D** Evidence gathered by scientists did not support sea-floor spreading.

Passage 2 The Himalayas are a range of mountains that is 2,400 km long and that arcs across Pakistan, India, Tibet, Nepal, Sikkim, and Bhutan. The Himalayas are the highest mountains on Earth. Nine mountains, including Mount Everest, the highest mountain on Earth, are more than 8,000 m tall. The formation of the Himalaya Mountains began about 80 million years ago. A tectonic plate carrying the Indian subcontinent collided with the Eurasian plate. The Indian plate was driven beneath the Eurasian plate. This collision caused the uplift of the Eurasian plate and the formation of the Himalayas. This process is continuing today.

1. In the passage, what does the word *arcs* mean?

- **A** forms a circle
- **B** forms a plane
- **C** forms a curve
- **D** forms a straight line

2. According to the passage, which geologic process formed the Himalaya Mountains?

- **F** divergence
- **G** subsidence
- **H** strike-slip faulting
- **I** convergence

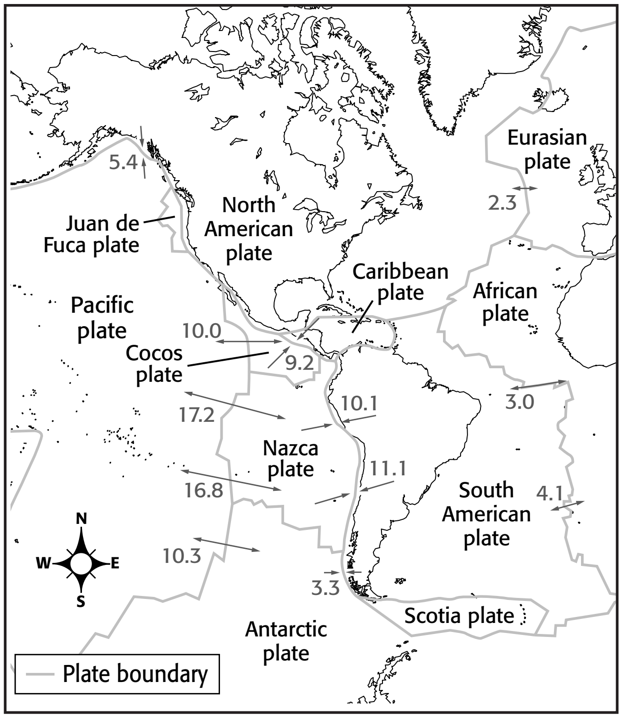
3. Which of the following statements is a fact according to the passage?

- **A** The nine tallest mountains on Earth are located in the Himalaya Mountains.
- **B** The Himalaya Mountains are located within six countries.
- **C** The Himalaya Mountains are the longest mountain range on Earth.
- **D** The Himalaya Mountains formed more than 80 million years ago.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

INTERPRETING GRAPHICS

The illustration below shows the relative velocities (in centimeters per year) and directions in which tectonic plates are separating and colliding. Arrows that point away from one another indicate plate separation. Arrows that point toward one another indicate plate collision. Use the illustration below to answer the questions that follow.



1. Between which two tectonic plates does spreading appear to be the fastest?
   - **A** the Australian plate and the Pacific plate
   - **B** the Antarctic plate and the Pacific plate
   - **C** the Nazca plate and the Pacific plate
   - **D** the Cocos plate and the Pacific plate

2. Where do you think mountain building is taking place?
   - **F** between the African plate and the South American plate
   - **G** between the Nazca plate and the South American plate
   - **H** between the North American plate and the Eurasian plate
   - **I** between the African plate and the North American plate

MATH

Read each question below, and choose the best answer.

1. The mesosphere is 2,550 km thick, and the asthenosphere is 250 km thick. If you assume that the lithosphere is 150 km thick and that the crust is 50 km thick, how thick is the mantle?
   - **A** 2,950 km
   - **B** 2,900 km
   - **C** 2,800 km
   - **D** 2,550 km

2. If a seismic wave travels through the mantle at an average velocity of 8 km/s, how many seconds will the wave take to travel through the mantle?
   - **F** 318.75 s
   - **G** 350.0 s
   - **H** 362.5 s
   - **I** 368.75 s

3. If the crust in a certain area is subsiding at the rate of 2 cm per year and has an elevation of 1,000 m, what elevation will the crust have in 10,000 years?
   - **A** 500 m
   - **B** 800 m
   - **C** 1,200 m
   - **D** 2,000 m

4. Assume that a very small oceanic plate is located between a mid-ocean ridge and a subduction zone. At the ridge, the plate is growing at a rate of 5 km every 1 million years. At the subduction zone, the plate is being destroyed at a rate of 10 km every 1 million years. If the oceanic plate is 100 km across, how long will it take the plate to disappear?
   - **F** 100 million years
   - **G** 50 million years
   - **H** 20 million years
   - **I** 5 million years

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Science in Action

Science, Technology, and Society

Using Satellites to Track Plate Motion

When you think of laser beams firing, you may think of science fiction movies. However, scientists use laser beams to determine the rate and direction of motion of tectonic plates. From ground stations on Earth, laser beams are fired at several small satellites orbiting 5,900 km above Earth. From the satellites, the laser beams are reflected back to ground stations. Differences in the time it takes signals to be reflected from targets are measured over a period of time. From these differences, scientists can determine the rate and direction of plate motion.

Social Studies ACTIVITY

WRITING SKILL Research a society that lives at an active plate boundary. Find out how the people live with dangers such as volcanoes and earthquakes. Include your findings in a short report.

This scientist is using a laser to test one of the satellites that will be used to track plate motion.

Scientific Discoveries

Megaplumes

Eruptions of boiling water from the sea floor form giant, spiral disks that twist through the oceans. Do you think it's impossible? Oceanographers have discovered these disks at eight locations at mid-ocean ridges over the past 20 years. These disks, which may be tens of kilometers across, are called *megaplumes*. Megaplumes are like blenders. They mix hot water with cold water in the oceans. Megaplumes can rise hundreds of meters from the ocean floor to the upper layers of the ocean. They carry gases and minerals and provide extra energy and food to animals in the upper layers of the ocean.

Language Arts ACTIVITY

WRITING SKILL Did you ever wonder about the origin of the name *Himalaya*? Research the origin of the name *Himalaya,* and write a short report about what you find.

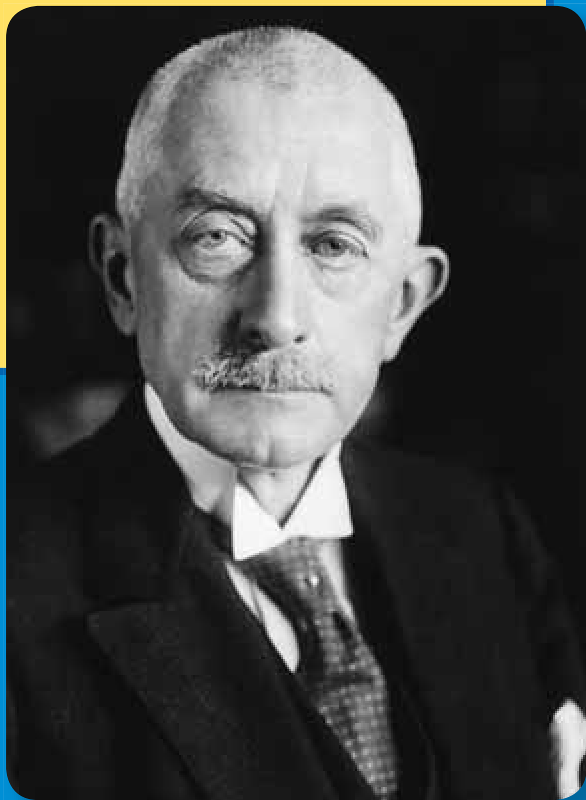
Copyright © by Holt, Rinehart and Winston. All rights reserved.

People in Science

Alfred Wegener

Continental Drift Alfred Wegener's greatest contribution to science was the hypothesis of continental drift. This hypothesis states that continents drift apart from one another and have done so in the past. To support his hypothesis, Wegener used geologic, fossil, and glacial evidence gathered on both sides of the Atlantic Ocean. For example, Wegener recognized similarities between rock layers in North America and Europe and between rock layers in South America and Africa. He believed that these similarities could be explained only if these geologic features were once part of the same continent.

Although continental drift explained many of his observations, Wegener could not find scientific evidence to develop a complete explanation of how continents move. Most scientists were skeptical of Wegener's hypothesis and dismissed it as foolishness. It was not until the 1950s and 1960s that the discoveries of magnetic reversals and sea-floor spreading provided evidence of continental drift.



Math ACTIVITY

The distance between South America and Africa is 7,200 km. As new crust is created at the mid-ocean ridge, South America and Africa are moving away from each other at a rate of about 3.5 cm per year. How many millions of years ago were South America and Africa joined?

To learn more about these Science in Action topics, visit **go.hrw.com** and type in the keyword **HZ5TECF.**

Current Science

Check out Current Science® articles related to this chapter by visiting go.hrw.com. Just type in the keyword HZ5CS07.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

5

Earthquakes

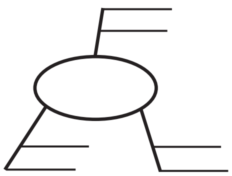
About the PHOTO

On January 17, 1995, an earthquake of magnitude 7.0 shook the area in and around Kobe, Japan. Though the earthquake lasted for less than a minute, more than 5,000 people lost their lives and another 300,000 people were left homeless. More than 200,000 buildings were damaged or destroyed. Large sections of the elevated Hanshin Expressway, shown in the photo, toppled when the columns supporting the expressway failed. The expressway passed over ground that was soft and wet, where the shaking was stronger and longer lasting.

PRE-READING ACTIVITY

Graphic Organizer

Spider Map Before you read the chapter, create the graphic organizer entitled "Spider Map" described in the **Study Skills** section of the Appendix. Label the circle "Earthquakes." Create a leg for each of the sections in this chapter. As you read the chapter, fill in the map with details about the material presented in each section of the chapter.



Copyright © by Holt, Rinehart and Winston. All rights reserved.

START-UP ACTIVITY

Bend, Break, or Shake

In this activity, you will test different materials in a model earthquake setting.

Procedure

1. Gather a **small wooden stick,** a **wire clothes hanger,** and a **plastic clothes hanger.**
2. Draw a straight line on a **sheet of paper.** Use a **protractor** to measure and draw the following angles from the line: 20°, 45°, and 90°.
3. Put on your **safety goggles.** Using the angles that you drew as a guide, try bending each item 20° and then releasing it. What happens? Does it break? If it bends, does it return to its original shape?
4. Repeat step 3, but bend each item 45°. Repeat the test again, but bend each item 90°.

Analysis

1. How do the different materials' responses to bending compare?
2. Where earthquakes happen, engineers use building materials that are flexible but that do not break or stay bent. Which materials from this experiment would you want building materials to behave like? Explain your answer.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 1

What Are Earthquakes?

Have you ever felt the earth move under your feet? Many people have. Every day, somewhere within this planet, an earthquake is happening.

READING WARM-UP

Objectives

- Explain where earthquakes take place.
- Explain what causes earthquakes.
- Identify three different types of faults that occur at plate boundaries.
- Describe how energy from earthquakes travels through the Earth.

Terms to Learn

seismology
deformation
elastic rebound
seismic waves
P waves
S waves

READING STRATEGY

Paired Summarizing Read this section silently. In pairs, take turns summarizing the material. Stop to discuss ideas that seem confusing.

The word *earthquake* defines itself fairly well. But there is more to earthquakes than just the shaking of the ground. An entire branch of Earth science, called **seismology** (siez MAHL uh jee), is devoted to studying earthquakes. Earthquakes are complex, and they present many questions for *seismologists,* the scientists who study earthquakes.

Where Do Earthquakes Occur?

Most earthquakes take place near the edges of tectonic plates. *Tectonic plates* are giant pieces of Earth's thin, outermost layer. Tectonic plates move around on top of a layer of plastic rock. **Figure 1** shows the Earth's tectonic plates and the locations of recent major earthquakes.

Tectonic plates move in different directions and at different speeds. Two plates can push toward or pull away from each other. They can also slip slowly past each other. As a result of these movements, numerous features called faults exist in the Earth's crust. A *fault* is a break in the Earth's crust along which blocks of the crust slide relative to one another. Earthquakes occur along faults because of this sliding.

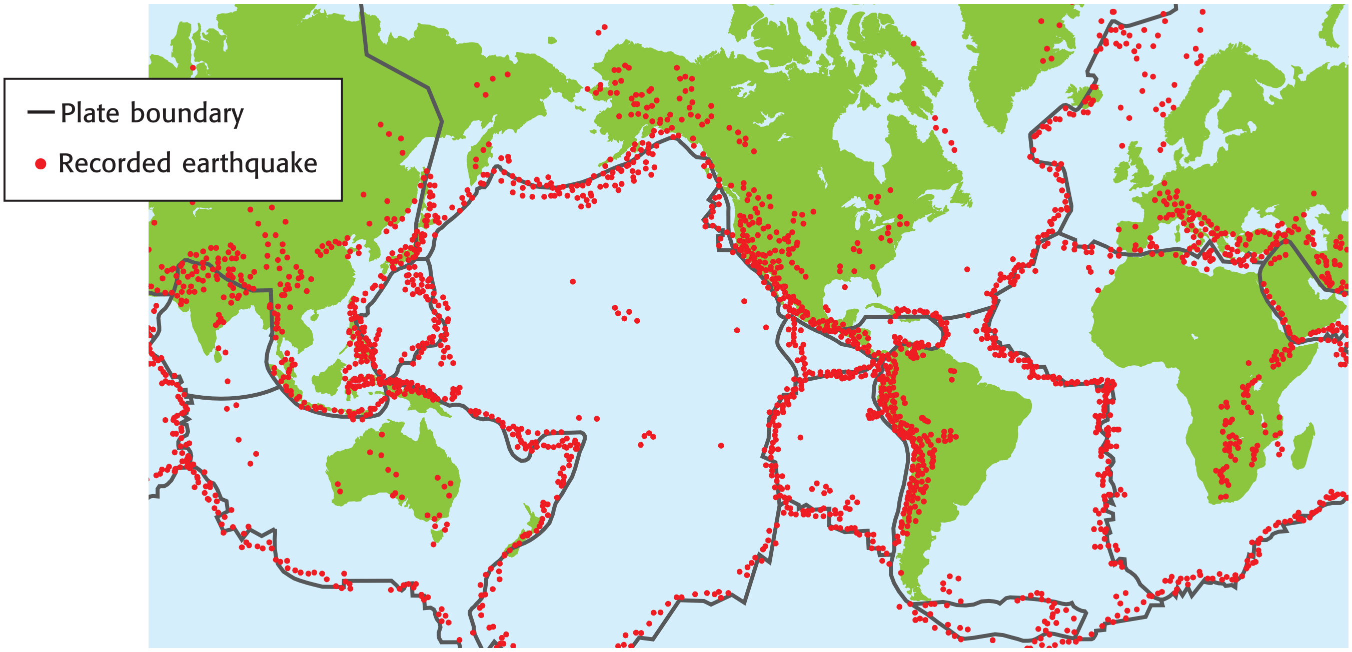


Figure 1 *The largest and most active earthquake zone lies along the plate boundaries surrounding the Pacific Ocean.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

What Causes Earthquakes?

As tectonic plates push, pull, or slip past each other, stress increases along faults near the plates' edges. In response to this stress, rock in the plates deforms. **Deformation** is the change in the shape of rock in response to stress. Rock along a fault deforms in mainly two ways. It deforms in a plastic manner, like a piece of molded clay, or in an elastic manner, like a rubber band. *Plastic deformation,* which is shown in **Figure 2,** does not lead to earthquakes.

Elastic deformation, however, does lead to earthquakes. Rock can stretch farther without breaking than steel can, but rock will break at some point. Think of elastically deformed rock as a stretched rubber band. You can stretch a rubber band only so far before it breaks. When the rubber band breaks, it releases energy. Then, the broken pieces return to their unstretched shape.

Figure 2 *This road cut is adjacent to the San Andreas Fault in southern California. The rocks in the cut have undergone deformation because of the continuous motion of the fault.*

Elastic Rebound

The sudden return of elastically deformed rock to its original shape is called **elastic rebound.** Elastic rebound is like the return of the broken rubber-band pieces to their unstretched shape. Elastic rebound occurs when more stress is applied to rock than the rock can withstand. During elastic rebound, energy is released. Some of this energy travels as seismic waves. These seismic waves cause an earthquake, as shown in **Figure 3.**

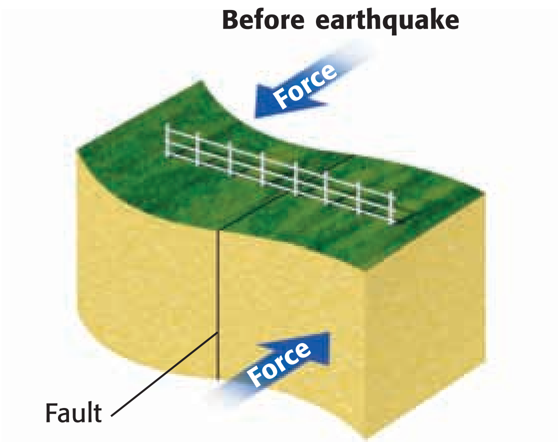
Reading Check **How does elastic rebound relate to earthquakes?** (*See the Appendix for answers to Reading Checks.*)

seismology the study of earthquakes

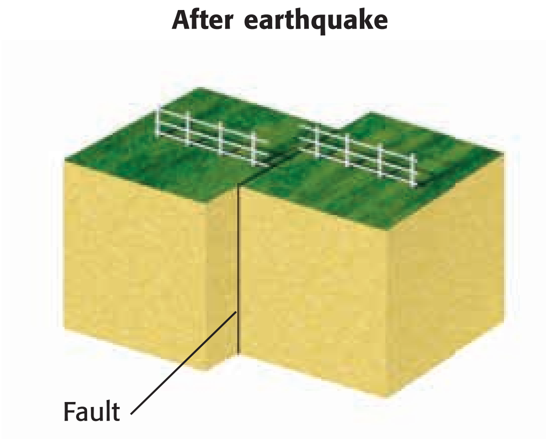
deformation the bending, tilting, and breaking of the Earth's crust; the change in the shape of rock in response to stress

elastic rebound the sudden return of elastically deformed rock to its undeformed shape

Figure 3 **Elastic Rebound and Earthquakes**



1 Tectonic forces push rock on either side of the fault in opposite directions, but the rock is locked together and does not move. The rock deforms in an elastic manner.



2 When enough stress is applied, the rock slips along the fault and releases energy.

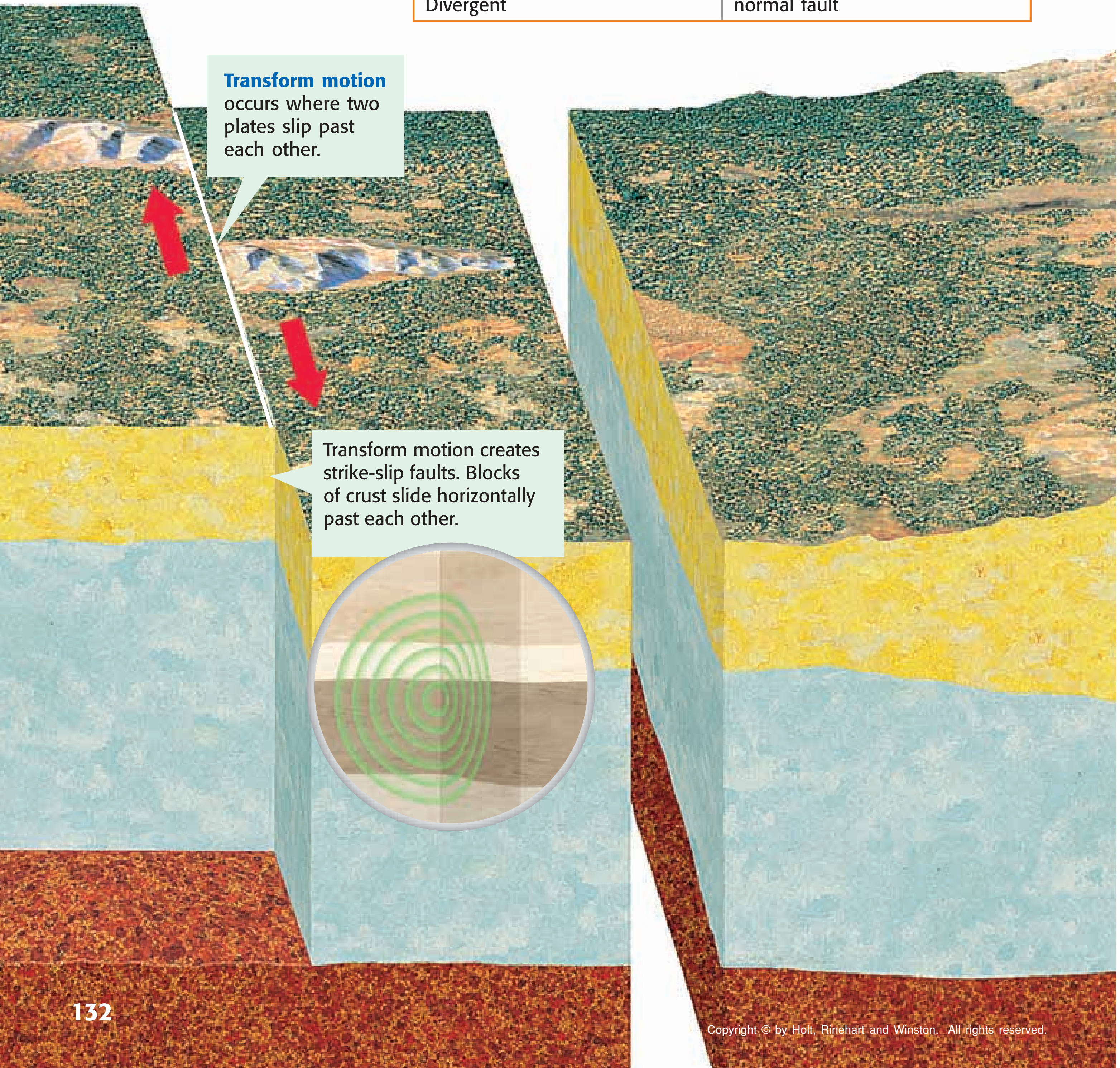
Copyright © by Holt, Rinehart and Winston. All rights reserved.

Faults at Tectonic Plate Boundaries

A specific type of plate motion takes place at different tectonic plate boundaries. Each type of motion creates a particular kind of fault that can produce earthquakes. Examine **Table 1** and the diagram below to learn more about plate motion.

Table 1 **Plate Motion and Fault Types**

Plate motion	Major fault type
Transform	strike-slip fault
Convergent	reverse fault
Divergent	normal fault

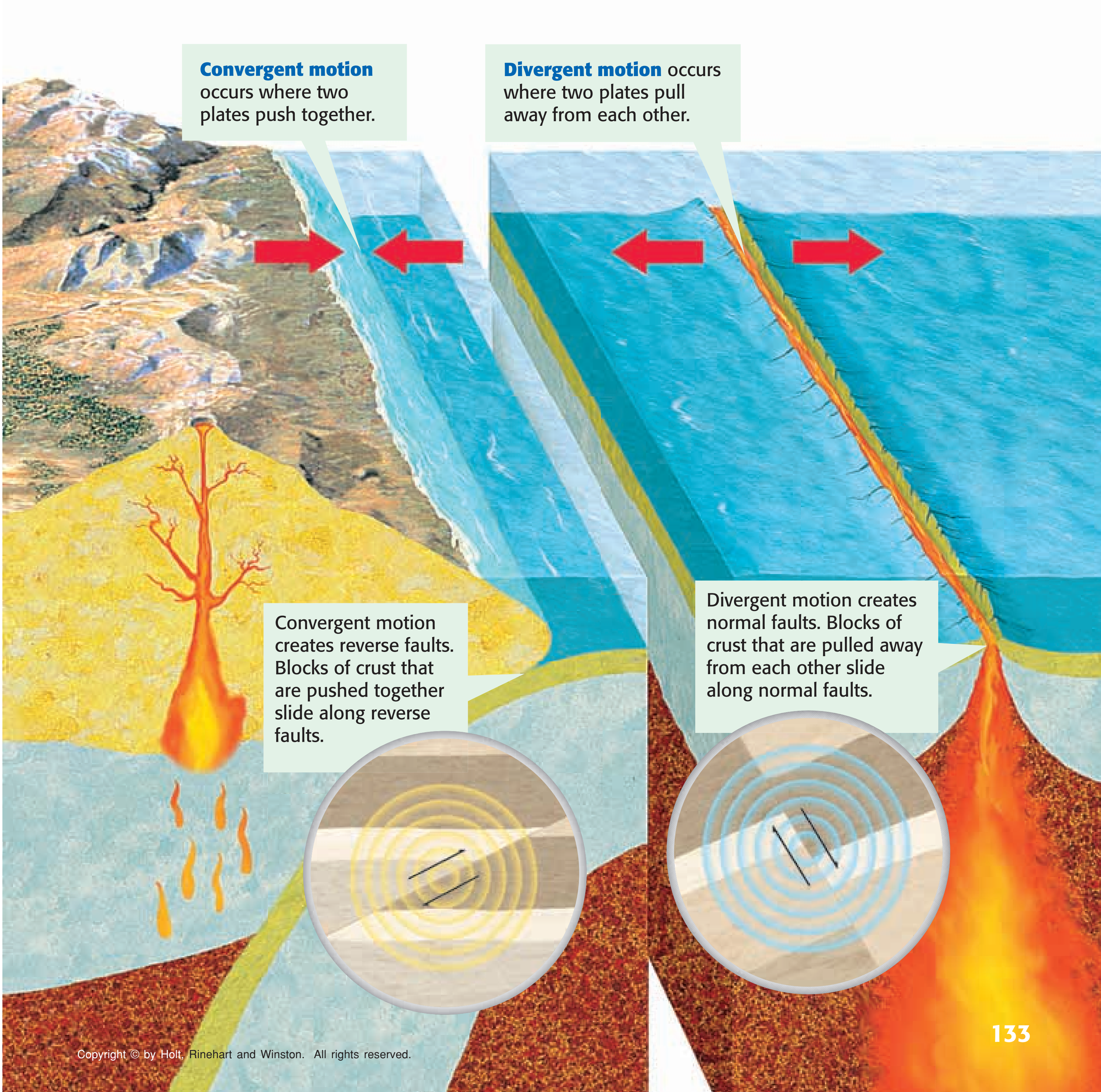


Copyright © by Holt, Rinehart and Winston. All rights reserved.

Earthquake Zones

Earthquakes can happen both near Earth's surface or far below it. Most earthquakes happen in the earthquake zones along tectonic plate boundaries. Earthquake zones are places where a large number of faults are located. The San Andreas Fault Zone in California is an example of an earthquake zone. But not all faults are located at tectonic plate boundaries. Sometimes, earthquakes happen along faults in the middle of tectonic plates.

Reading Check Where are earthquake zones located?



Copyright © by Holt, Rinehart and Winston. All rights reserved.

How Do Earthquake Waves Travel?

Waves of energy that travel through the Earth are called **seismic waves.** Seismic waves that travel through the Earth's interior are called *body waves*. There are two types of body waves: P waves and S waves. Seismic waves that travel along the Earth's surface are called *surface waves*. Each type of seismic wave travels through Earth's layers in a different way and at a different speed. Also, the speed of a seismic wave depends on the kind of material the wave travels through.

P Waves

Waves that travel through solids, liquids, and gases are called **P waves** (pressure waves). They are the fastest seismic waves, so P waves always travel ahead of other seismic waves. P waves are also called *primary waves,* because they are always the first waves of an earthquake to be detected. To understand how P waves affect rock, imagine a cube of gelatin sitting on a plate. Like most solids, gelatin is an elastic material. It wiggles if you tap it. Tapping the cube of gelatin changes the pressure inside the cube, which momentarily deforms the cube. The gelatin then reacts by springing back to its original shape. This process is how P waves affect rock, as shown in **Figure 4.**

S Waves

Rock can also be deformed from side to side. After being deformed from side to side, the rock springs back to its original position and S waves are created. **S waves,** or shear waves, are the second-fastest seismic waves. S waves shear rock side to side, as shown in **Figure 4,** which means they stretch the rock sideways. Unlike P waves, S waves cannot travel through parts of the Earth that are completely liquid. Also, S waves are slower than P waves and always arrive later. Thus, another name for S waves is *secondary waves*.

Quick Lab

Modeling Seismic Waves

1. Stretch a **spring toy** lengthwise on a **table.**
2. Hold one end of the spring while a partner holds the other end. Push your end toward your partner's end, and observe what happens.
3. Repeat step 2, but this time shake the spring from side to side.
4. Which type of seismic wave is represented in step 2? in step 3?

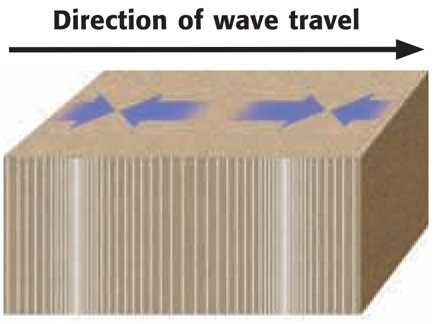
seismic wave a wave of energy that travels through the Earth, away from an earthquake in all directions

P wave a seismic wave that causes particles of rock to move in a back-and-forth direction

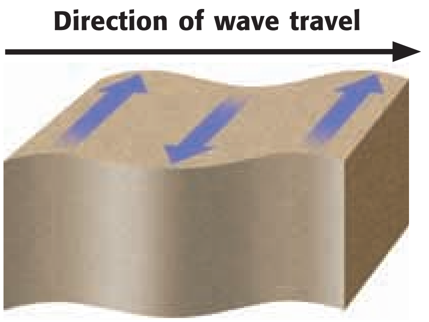
S wave a seismic wave that causes particles of rock to move in a side-to-side direction

Figure 4 **Body Waves**

P waves move rock back and forth, which squeezes and stretches the rock, as they travel through the rock.



S waves shear rock side to side as they travel through the rock.



Copyright © by Holt, Rinehart and Winston. All rights reserved.

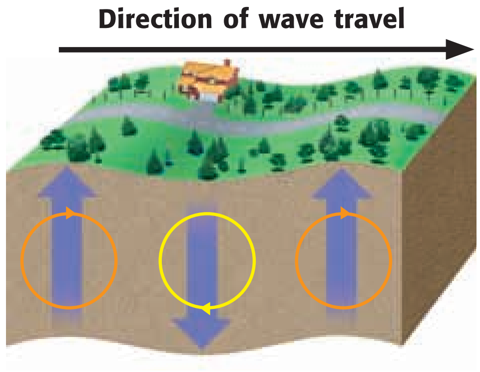
Surface Waves

Surface waves move along the Earth's surface and produce motion mostly in the upper few kilometers of Earth's crust. There are two types of surface waves. One type of surface wave produces motion up, down, and around, as shown in **Figure 5.** The other type produces back-and-forth motion like the motion produced by S waves. Surface waves are different from body waves in that surface waves travel more slowly and are more destructive.

Reading Check **Explain the differences between surface waves and body waves.**

Figure 5 **Surface Waves**

Surface waves move the ground much like ocean waves move water particles.



SECTION Review

Summary

- Earthquakes occur mainly near the edges of tectonic plates.
- Elastic rebound is the direct cause of earthquakes.
- Three major types of faults occur at tectonic plate boundaries: normal faults, reverse faults, and strike-slip faults.
- Earthquake energy travels as body waves through the Earth's interior or as surface waves along the surface of the Earth.

Using Key Terms

Complete each of the following sentences by choosing the correct term from the word bank.

Deformation	P waves
Elastic rebound	S waves

1. _____ is the change in shape of rock due to stress.
2. _____ always travel ahead of other waves.

Understanding Key Ideas

3. Seismic waves that shear rock side to side are called
   - **a.** surface waves.
   - **b.** S waves.
   - **c.** P waves.
   - **d.** Both (b) and (c)
4. Where do earthquakes occur?
5. What is the direct cause of earthquakes?
6. Describe the three types of plate motion and the faults that are characteristic of each type of motion.
7. What is an earthquake zone?

Math Skills

8. A seismic wave is traveling through the Earth at an average rate of speed of 8 km/s. How long will it take the wave to travel 480 km?

Critical Thinking

9. **Applying Concepts** Given what you know about elastic rebound, why do you think some earthquakes are stronger than others?
10. **Identifying Relationships** Why are surface waves more destructive to buildings than P waves or S waves are?
11. **Identifying Relationships** Why do you think the majority of earthquake zones are located at tectonic plate boundaries?

SCILINKS
NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: What Is an Earthquake?
SciLinks code: HSM1658

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 2

Earthquake Measurement

Imagine walls shaking, windows rattling, and glassware and dishes clinking and clanking. After only seconds, the vibrating stops and the sounds die away.

Within minutes, news reports give information about the strength, the time, and the location of the earthquake. You are amazed at how scientists could have learned this information so quickly.

Locating Earthquakes

How do seismologists know when and where earthquakes begin? They depend on earthquake-sensing instruments called seismographs. **Seismographs** are instruments located at or near the surface of the Earth that record seismic waves. When the waves reach a seismograph, the seismograph creates a seismogram. A **seismogram** is a tracing of earthquake motion and is created by a seismograph.

Determining Time and Location of Earthquakes

Seismologists use seismograms to calculate when an earthquake began. Seismologists find an earthquake's start time by comparing seismograms and noting the differences in arrival times of P waves and S waves. Seismologists also use seismograms to find an earthquake's epicenter. An **epicenter** is the point on the Earth's surface directly above an earthquake's starting point. A **focus** is the point inside the Earth where an earthquake begins. **Figure 1** shows the location of an earthquake's epicenter and its focus.

Reading Check **How do seismologists determine an earthquake's start time?** (*See the Appendix for answers to Reading Checks.*)

READING WARM-UP

Objectives

- Explain how earthquakes are detected.
- Describe how to locate an earthquake's epicenter.
- Explain how the strength of an earthquake is measured.
- Explain how the intensity of an earthquake is measured.

Terms to Learn

seismograph   epicenter
seismogram   focus

READING STRATEGY

Reading Organizer As you read this section, create an outline of the section. Use the headings from the section in your outline.

seismograph an instrument that records vibrations in the ground and determines the location and strength of an earthquake

seismogram a tracing of earthquake motion that is created by a seismograph

epicenter the point on Earth's surface directly above an earthquake's starting point, or focus

focus the point along a fault at which the first motion of an earthquake occurs

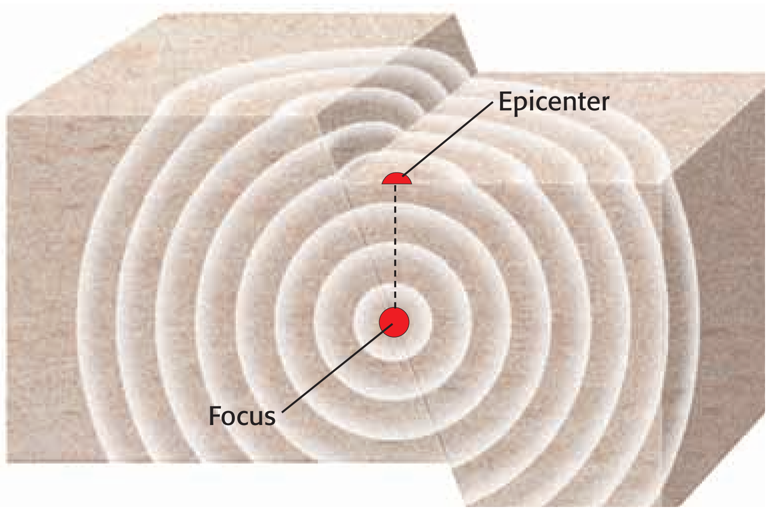


Figure 1 *An earthquake's epicenter is on the Earth's surface directly above the earthquake's focus.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

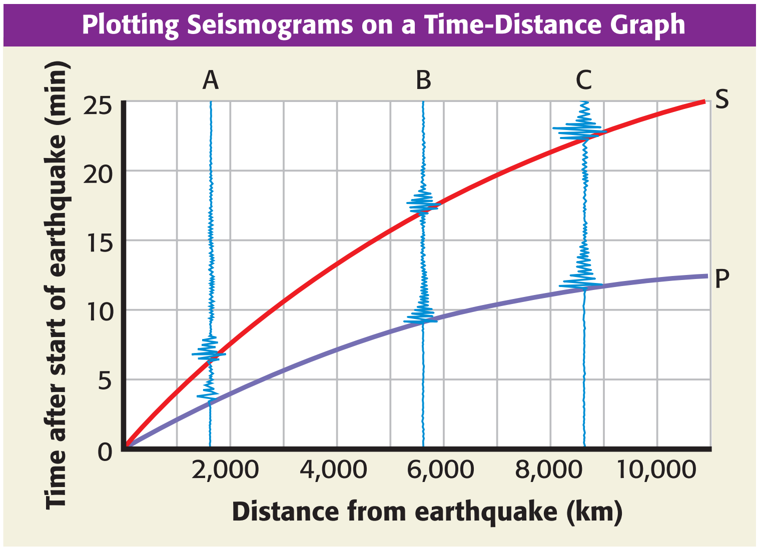


Figure 2 *After identifying P and S waves, seismologists can use the time difference to determine an earthquake's start time and the distance from the epicenter to each station. The vertical axis tells how much time passed between the start of the earthquake and the arrival of seismic waves at a station. The horizontal axis tells the distance between a station and the earthquake's epicenter.*

The S-P Time Method

Perhaps the simplest method by which seismologists find an earthquake's epicenter is the *S-P time method*. The first step in this method is to collect several seismograms of the same earthquake from different locations. Then, the seismograms are placed on a time-distance graph. The seismogram tracing of the first P wave is lined up with the P-wave time-distance curve, and the tracing of the first S wave is lined up with the S-wave curve, as shown in **Figure 2.** The distance of each station from the earthquake can be found by reading the horizontal axis. After finding out the distances, a seismologist can locate an earthquake's epicenter, as shown in **Figure 3.**

Figure 3 **Finding an Earthquake's Epicenter**

1. A circle is drawn around a seismograph station. The radius of the circle equals the distance from the seismograph to the epicenter. (This distance is taken from the time-distance graph.)

2. When a second circle is drawn around another seismograph station, the circle overlaps the first circle in two spots. One of these spots is the earthquake's epicenter.

3. When a circle is drawn around a third seismograph station, all three circles intersect in one spot—the earthquake's epicenter. In this case, the epicenter was in San Francisco.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Measuring Earthquake Strength and Intensity

"How strong was the earthquake?" is a common question asked of seismologists. This question is not easy to answer. But it is an important question for anyone living near an earthquake zone. Fortunately, seismograms can be used not only to determine an earthquake's epicenter and its start time but also to find out an earthquake's strength.

CONNECTION TO Social Studies

WRITING SKILL **New Madrid Earthquakes**

During the winter of 1811–1812, three of the most powerful earthquakes in U.S. history were centered near New Madrid, Missouri, thousands of miles from the nearest tectonic plate boundary. Research the New Madrid earthquakes, and summarize your findings in a one-page essay.

The Richter Magnitude Scale

Throughout much of the 20th century, seismologists used the *Richter magnitude scale*, commonly called the Richter scale, to measure the strength of earthquakes. Seismologist Charles Richter created the scale in the 1930s. Richter wanted to compare earthquakes by measuring ground motion recorded by seismograms at seismograph stations.

Earthquake Ground Motion

A measure of the strength of an earthquake is called *magnitude*. The Richter scale measures the ground motion from an earthquake and adjusts for distance to find its strength. Each time the magnitude increases by one unit, the measured ground motion becomes 10 times larger. For example, an earthquake with a magnitude of 5.0 on the Richter scale will produce 10 times as much ground motion as an earthquake with a magnitude of 4.0. Furthermore, an earthquake with a magnitude of 6.0 will produce 100 times as much ground motion (10 × 10) as an earthquake with a magnitude of 4.0. **Table 1** shows the differences in the estimated effects of earthquakes with each increase of one unit of magnitude.

Reading Check **How are magnitude and ground motion related in the Richter scale?**

Table 1 **Effects of Different-Sized Earthquakes**

Magnitude	Estimated effects
2.0	can be detected only by seismograph
3.0	can be felt at epicenter
4.0	can be felt by most people in the area
5.0	causes damage at epicenter
6.0	can cause widespread damage
7.0	can cause great, widespread damage

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Modified Mercalli Intensity Scale

A measure of the degree to which an earthquake is felt by people and the amount of damage caused by the earthquake, if any, is called *intensity*. Currently, seismologists in the United States use the Modified Mercalli Intensity Scale to measure earthquake intensity. This scale is a numerical scale that uses Roman numerals from I to XII to describe increasing earthquake intensity levels. An intensity level of I describes an earthquake that is not felt by most people. An intensity level of XII indicates total damage of an area. **Figure 4** shows the type of damage caused by an earthquake that has a Modified Mercalli intensity level of XI.

Because the effects of an earthquake vary from place to place, any earthquake will have more than one intensity value. Intensity values are usually higher near an earthquake's epicenter.

Figure 4 *Intensity values for the 1906 San Francisco earthquake varied from place to place. The maximum intensity level was XI.*

SECTION Review

Summary

- Seismologists detect seismic waves and record them as seismograms.
- The S-P time method is the simplest method to use to find an earthquake's epicenter.
- Seismologists use the Richter scale to measure an earthquake's strength.
- Seismologists use the Modified Mercalli Intensity Scale to measure an earthquake's intensity.

Using Key Terms

1. In your own words, write a definition for each of the following terms: *epicenter* and *focus*.

Understanding Key Ideas

2. What is the difference between a seismograph and a seismogram?
3. Explain how earthquakes are detected.
4. Briefly explain the steps of the S-P time method for locating an earthquake's epicenter.
5. Why might an earthquake have more than one intensity value?

Math Skills

6. How much more ground motion is produced by an earthquake of magnitude 7.0 than by an earthquake of magnitude 4.0?

Critical Thinking

7. **Making Inferences** Why is a 6.0 magnitude earthquake so much more destructive than a 5.0 magnitude earthquake?
8. **Identifying Bias** Which do you think is the more important measure of earthquakes, strength or intensity? Explain.
9. **Making Inferences** Do you think an earthquake of moderate magnitude can produce high Modified Mercalli intensity values?

SCILINKS® NSTA
Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Earthquake Measurement
SciLinks code: HSM0452

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 3

Earthquakes and Society

Imagine that you are in class and the ground begins to shake beneath your feet. What do you do?

Seismologists are not able to predict the exact time when and place where an earthquake will occur. They can, at best, make forecasts based on the frequency with which earthquakes take place. Therefore, seismologists are always looking for better ways to forecast when and where earthquakes will happen. In the meantime, it is important for people in earthquake zones to be prepared before an earthquake strikes.

READING WARM-UP

Objectives

- Explain how earthquake-hazard level is determined.
- Compare methods of earthquake forecasting.
- Describe five ways to safeguard buildings against earthquakes.
- Outline earthquake safety procedures.

Terms to Learn

gap hypothesis
seismic gap

READING STRATEGY

Discussion Read this section silently. Write down questions that you have about this section. Discuss your questions in a small group.

Earthquake Hazard

Earthquake hazard is a measurement of how likely an area is to have damaging earthquakes in the future. An area's earthquake-hazard level is determined by past and present seismic activity. The map in **Figure 1** shows that some areas of the United States have a higher earthquake-hazard level than others do. This variation is caused by differences in seismic activity. The greater the seismic activity, the higher the earthquake-hazard level. The West Coast, for example, has a very high earthquake-hazard level because it has a lot of seismic activity.

Look at the map. What earthquake-hazard level or levels are shown in the area in which you live? How do the hazard levels of nearby areas compare with your area's hazard level?

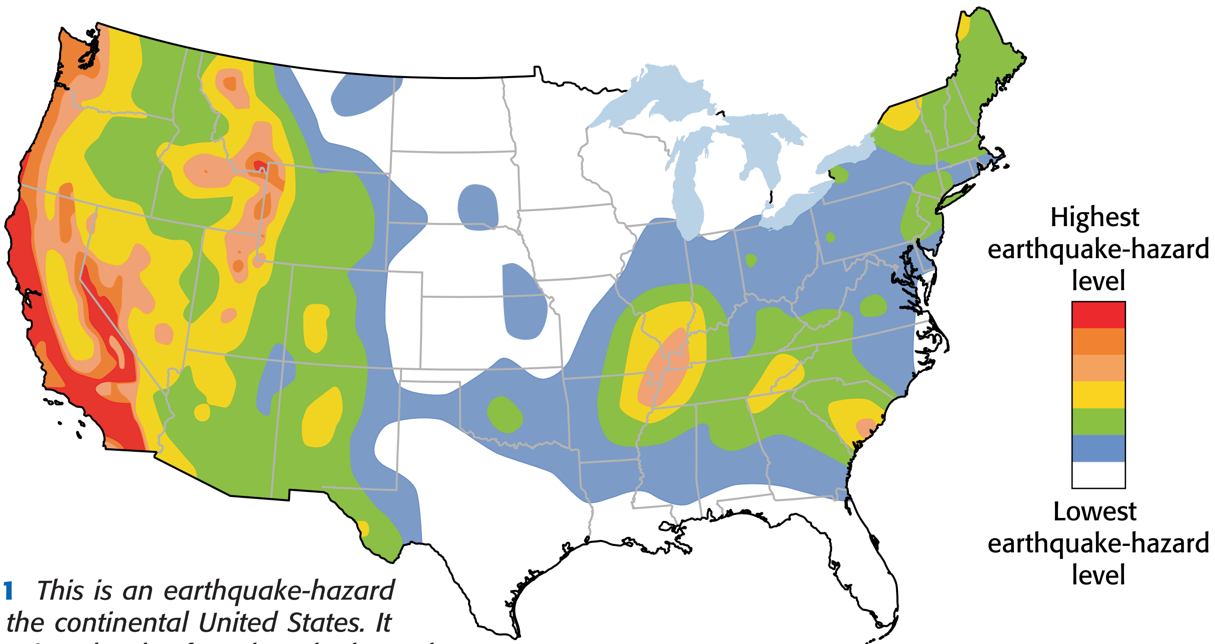


Figure 1 *This is an earthquake-hazard map of the continental United States. It shows various levels of earthquake hazard for different areas of the country.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Table 1 Worldwide Earthquake Frequency (Based on Observations Since 1900)

Descriptor	Magnitude	Average number annually
Great	8.0 and higher	1
Major	7.0–7.9	18
Strong	6.0–6.9	120
Moderate	5.0–5.9	800
Light	4.0–4.9	about 6,200
Minor	3.0–3.9	about 49,000
Very minor	2.0–2.9	about 365,000

Earthquake Forecasting

Forecasting when and where earthquakes will occur and their strength is difficult. By looking carefully at areas of seismic activity, seismologists have discovered some patterns in earthquakes that allow them to make some general predictions.

Strength and Frequency

Earthquakes vary in strength. And you can probably guess that earthquakes don't occur on a set schedule. But what you may not know is that the strength of earthquakes is related to how often they occur. **Table 1** provides more detail about this relationship worldwide.

The relationship between earthquake strength and frequency is also at work on a local scale. For example, each year approximately 1.6 earthquakes with a magnitude of 4.0 on the Richter scale occur in the Puget Sound area of Washington State. Over this same time period, approximately 10 times as many earthquakes with a magnitude of 3.0 occur in this area. Scientists use these statistics to make forecasts about the strength, location, and frequency of future earthquakes.

Reading Check **What is the relationship between the strength of earthquakes and earthquake frequency?** (*See the Appendix for answers to Reading Checks.*)

The Gap Hypothesis

Another method of forecasting an earthquake's strength, location, and frequency is based on the gap hypothesis. The **gap hypothesis** is a hypothesis that states that sections of active faults that have had relatively few earthquakes are likely to be the sites of strong earthquakes in the future. The areas along a fault where relatively few earthquakes have occurred are called **seismic gaps.**

INTERNET ACTIVITY

For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HZ5EQKW.**

gap hypothesis a hypothesis that is based on the idea that a major earthquake is more likely to occur along the part of an active fault where no earthquakes have occurred for a certain period of time

seismic gap an area along a fault where relatively few earthquakes have occurred recently but where strong earthquakes have occurred in the past

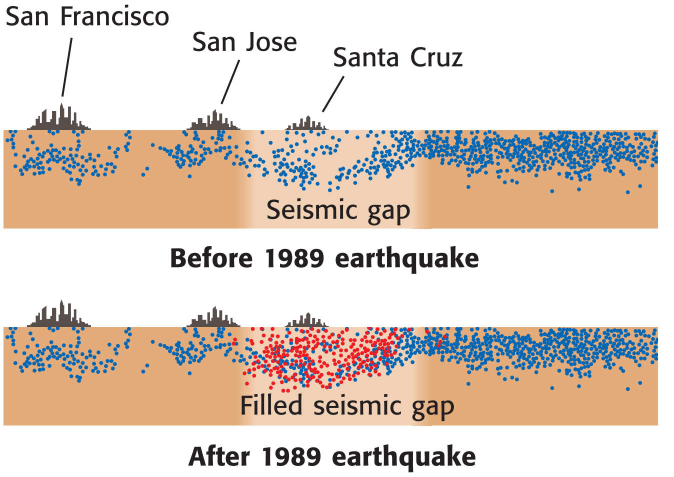
Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 2 **A Seismic Gap on the San Andreas Fault**

This diagram shows a cross section of the San Andreas Fault. Note how the seismic gap was filled by the 1989 Loma Prieta earthquake and its aftershocks. *Aftershocks* are weaker earthquakes that follow a stronger earthquake.

● Earthquakes prior to 1989 earthquake

● 1989 earthquake and aftershocks



Using the Gap Hypothesis

Not all seismologists believe the gap hypothesis is an accurate method of forecasting earthquakes. But some seismologists think the gap hypothesis helped forecast the approximate location and strength of the 1989 Loma Prieta earthquake in the San Francisco Bay area. The seismic gap that they identified is illustrated in **Figure 2.** In 1988, these seismologists predicted that over the next 30 years there was a 30% chance that an earthquake with a magnitude of at least 6.5 would fill this seismic gap. Were they correct? The Loma Prieta earthquake, which filled in the seismic gap in 1989, measured 6.9 on the Richter scale. Their prediction was very close, considering how complicated the forecasting of earthquakes is.

Figure 3 *During the January 17, 1995, earthquake, the fronts of entire buildings collapsed into the streets of Kobe, Japan.*

Earthquakes and Buildings

Figure 3 shows what can happen to buildings during an earthquake. These buildings were not designed or constructed to withstand the forces of an earthquake.

Today, older structures in seismically active places, such as California, are being made more earthquake resistant. The process of making older structures more earthquake resistant is called *retrofitting*. A common way to retrofit an older home is to securely fasten it to its foundation. Steel can be used to strengthen structures made of brick.

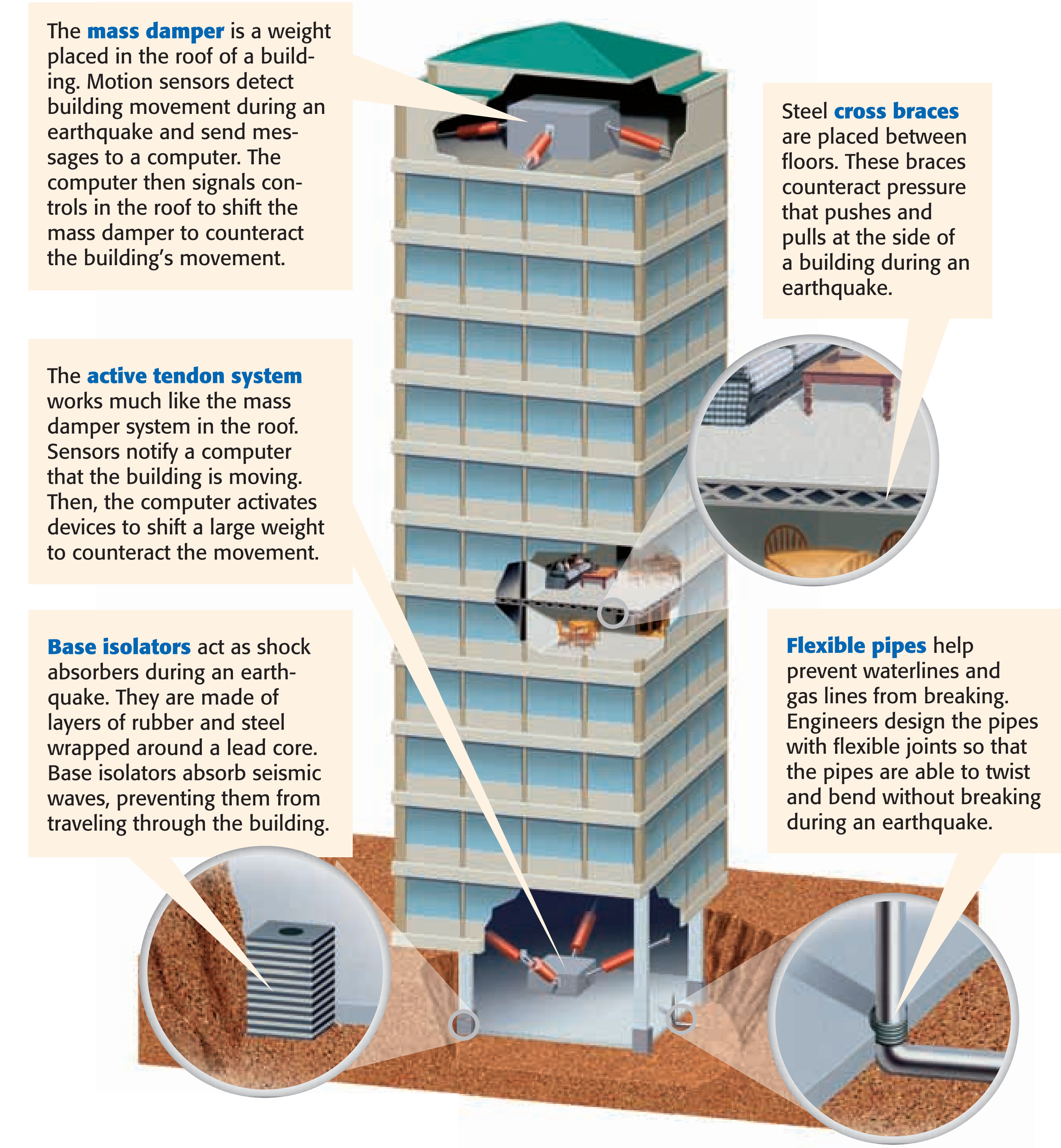
Reading Check **Explain the meaning of the term *retrofitting*.**

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Earthquake-Resistant Buildings

A lot has been learned from building failure during earthquakes. Armed with this knowledge, architects and engineers use the newest technology to design and construct buildings and bridges to better withstand earthquakes. Carefully study **Figure 4** to learn more about this modern technology.

Figure 4 **Earthquake-Resistant Building Technology**



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Are You Prepared for an Earthquake?

If you live in an area where earthquakes are common, there are many things you can do to protect yourself and your property from earthquakes. Plan ahead so that you will know what to do before, during, and after an earthquake. Stick to your plan as closely as possible.

CONNECTION TO Physics

WRITING SKILL **Earthquake Proof Buildings** During earthquakes, buildings often sway from side to side when the ground beneath them moves. This swaying can cause structural damage to buildings. Scientists and engineers are developing computer-controlled systems that counteract the swaying of buildings during earthquakes. Research a computer-controlled system that uses mass dampers or active tendons to reduce damage to buildings. Summarize your research in a short essay.

Before the Shaking Starts

The first thing you should do is safeguard your home against earthquakes. You can do so by putting heavier objects on lower shelves so that they do not fall during the earthquake. You can also talk to a parent about having your home strengthened. Next, you should find safe places within each room of your home and outside of your home. Then, make a plan with others (your family, neighbors, or friends) to meet in a safe place after the earthquake is over. This plan ensures that you will all know who is safe. During the earthquake, waterlines, power lines, and roadways may be damaged. So, you should store water, nonperishable food, a fire extinguisher, a flashlight with batteries, a portable radio, medicines, and a first-aid kit in a place you can access after the earthquake.

When the Shaking Starts

The best thing to do if you are indoors when an earthquake begins is to crouch or lie face down under a table or desk in the center of a room, as shown in **Figure 5.** If you are outside, lie face down away from buildings, power lines, and trees and cover your head with your hands. If you are in a car on an open road, you should stop the car and remain inside.

Reading Check **Explain what you would do if you were in class and an earthquake began to shake the ground.**

Figure 5 *These students are participating in an earthquake drill.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

After the Shaking Stops

Being in an earthquake is a startling and often frightening experience for most people. After being in an earthquake, you should not be surprised to find yourself and others puzzled about what took place. You should try to calm down and get your bearings as quickly as possible. Then, remove yourself from immediate danger, such as downed power lines, broken glass, and fire hazards. Always stay out of damaged buildings, and return home only when you are told that it is safe to do so by someone in authority. Be aware that there may be aftershocks, which may cause more damage to structures. Recall your earthquake plan, and follow it.

SCHOOL to HOME

Disaster Planning

With your parent, create a plan that will protect your family in the event of a natural disaster, such as an earthquake. The plan should include steps to take before, during, and after a disaster. Present your disaster plan in the form of an oral report to your class.

ACTIVITY

SECTION Review

Summary

- Earthquake hazard is a measure of how likely an area is to have earthquakes in the future.
- Seismologists use their knowledge of the relationship between earthquake strength and frequency and of the gap hypothesis to forecast earthquakes.
- Homes and buildings and bridges can be strengthened to decrease earthquake damage.
- People who live in earthquake zones should safeguard their home against earthquakes.

Using Key Terms

1. In your own words, write a definition for each of the following terms: *gap hypothesis* and *seismic gap*.

Understanding Key Ideas

2. A weight that is placed on a building to make the building earthquake resistant is called a(n)
   a. active tendon system.
   b. cross brace.
   c. mass damper.
   d. base isolator.
3. How is an area's earthquake-hazard level determined?
4. Compare the strength and frequency method with the gap hypothesis method for predicting earthquakes.
5. What is a common way of making homes more earthquake resistant?
6. Describe four pieces of technology that are designed to make buildings earthquake resistant.
7. Name five items that you should store in case of an earthquake.

Math Skills

8. Of the approximately 420,000 earthquakes recorded each year, about 140 have a magnitude greater than 6.0. What percentage of total earthquakes have a magnitude greater than 6.0?

Critical Thinking

9. **Evaluating Hypotheses** Seismologists predict that there is a 20% chance that an earthquake of magnitude 7.0 or greater will fill a seismic gap during the next 50 years. Is the hypothesis incorrect if the earthquake does not happen? Explain your answer.
10. **Applying Concepts** Why is a large earthquake often followed by numerous aftershocks?

SCILINKS® NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Earthquakes and Society
SciLinks code: HSM0455

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Using Scientific Methods

Inquiry Lab

Quake Challenge

In many parts of the world, people must have earthquakes in mind when they construct buildings. Each building must be designed so that the structure is protected during an earthquake. Architects have greatly improved the design of buildings since 1906, when an earthquake and the fires it caused destroyed much of San Francisco. In this activity, you will use marshmallows and toothpicks to build a structure that can withstand a simulated earthquake. In the process, you will discover some of the ways a building can be built to withstand an earthquake.

OBJECTIVES

Build a model of a structure that can withstand a simulated earthquake.

Evaluate ways in which you can strengthen your model.

MATERIALS

- gelatin, square, approximately 8 × 8 cm
- marshmallows (10)
- paper plate
- toothpicks (10)

SAFETY

Ask a Question

1. What features help a building withstand an earthquake? How can I use this information to build my structure?

Form a Hypothesis

2. Brainstorm with a classmate to design a structure that will resist the simulated earthquake. Write two or three sentences to describe your design. Explain why you think your design will be able to withstand a simulated earthquake.

Test the Hypothesis

3. Follow your design to build a structure using the toothpicks and marshmallows.
4. Set your structure on a square of gelatin, and place the gelatin on a paper plate.
5. Shake the square of gelatin to test whether your building will remain standing during a quake. Do not pick up the gelatin.
6. If your first design does not work well, change it until you find a design that does. Try to determine why your building is falling so that you can improve your design each time.
7. Sketch your final design.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

8. After you have tested your final design, place your structure on the gelatin square on your teacher's desk.

9. When every group has added a structure to the teacher's gelatin, your teacher will simulate an earthquake by shaking the gelatin. Watch to see which buildings withstand the most severe quake.

Analyze the Results

1. **Explaining Events** Which buildings were still standing after the final earthquake? What features made them more stable?

2. **Analyzing Results** How would you change your design in order to make your structure more stable?

Draw Conclusions

3. **Evaluating Models** This was a simple model of a real-life problem for architects. Based on this activity, what advice would you give to architects who design buildings in earthquake zones?

4. **Evaluating Models** What are some limitations of your earthquake model?

5. **Making Predictions** How could your research have an impact on society?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Chapter Review

USING KEY TERMS

1. Use each of the following terms in a separate sentence: *seismic wave, P wave,* and *S wave.*

For each pair of terms, explain how the meanings of the terms differ.

2. *seismograph* and *seismogram*

3. *epicenter* and *focus*

4. *gap hypothesis* and *seismic gap*

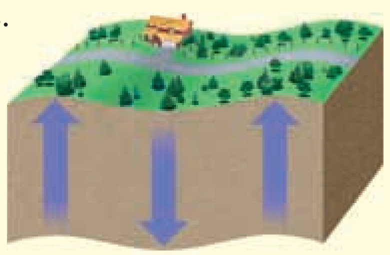
UNDERSTANDING KEY IDEAS

Multiple Choice

5. When rock is ___, energy builds up in it. Seismic waves occur as this energy is ___.
   - **a.** plastically deformed, increased
   - **b.** elastically deformed, released
   - **c.** plastically deformed, released
   - **d.** elastically deformed, increased

6. Reverse faults are created
   - **a.** by divergent plate motion.
   - **b.** by convergent plate motion.
   - **c.** by transform plate motion.
   - **d.** All of the above

7. The last seismic waves to arrive are
   - **a.** P waves.
   - **b.** body waves.
   - **c.** S waves.
   - **d.** surface waves.



8. If an earthquake begins while you are in a building, the safest thing for you to do is
   - **a.** to run out into an open space.
   - **b.** to get under the strongest table, chair, or other piece of furniture.
   - **c.** to call home.
   - **d.** to crouch near a wall.

9. How many major earthquakes (magnitude 7.0 to 7.9) happen on average in the world each year?
   - **a.** 1
   - **b.** 18
   - **c.** 120
   - **d.** 800

10. ___ counteract pressure that pushes and pulls at the side of a building during an earthquake.
    - **a.** Base isolators
    - **b.** Mass dampers
    - **c.** Active tendon systems
    - **d.** Cross braces

Short Answer

11. Can the S-P time method be used with one seismograph station to locate the epicenter of an earthquake? Explain your answer.

12. Explain how the Richter scale and the Modified Mercalli Intensity Scale are different.

13. What is the relationship between the strength of earthquakes and earthquake frequency?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

14 Explain the way that different seismic waves affect rock as they travel through it.

15 Describe some steps you can take to protect yourself and your property from earthquakes.

CRITICAL THINKING

16 **Concept Mapping** Use the following terms to create a concept map: *focus, epicenter, earthquake start time, seismic waves, P waves,* and *S waves.*

17 **Identifying Relationships** Would a strong or light earthquake be more likely to happen along a major fault where there have not been many recent earthquakes? Explain. (Hint: Think about the average number of earthquakes of different magnitudes that occur annually.)

18 **Applying Concepts** Japan is located near a point where three tectonic plates converge. What would you imagine the earthquake-hazard level in Japan to be? Explain why.

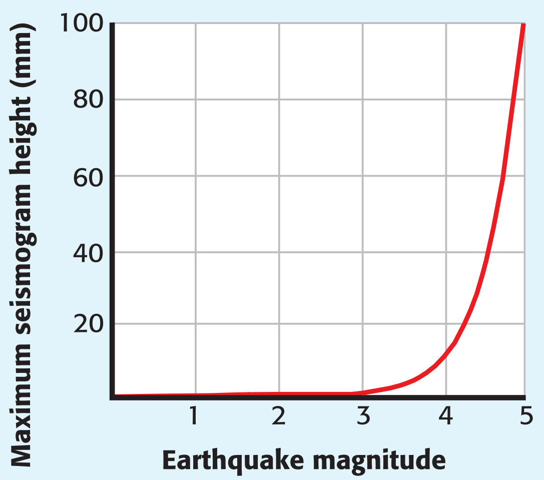
19 **Applying Concepts** You learned that if you are in a car during an earthquake and are out in the open, it is best to stay in the car. Can you think of any situation in which you might want to leave a car during an earthquake?

20 **Identifying Relationships** You use gelatin to simulate rock in an experiment in which you are investigating the way different seismic waves affect rock. In what ways is your gelatin model limited?

INTERPRETING GRAPHICS

The graph below illustrates the relationship between earthquake magnitude and the height of tracings on a seismogram. Charles Richter initially formed his magnitude scale by comparing the heights of seismogram readings for different earthquakes. Use the graph below to answer the questions that follow.

Seismogram Height Vs. Earthquake Magnitude

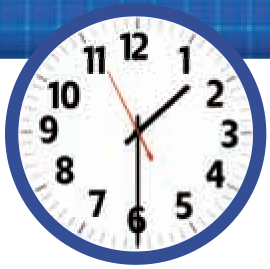


21 According to the graph, what would the magnitude of an earthquake be if its maximum seismograph height is 10 mm?

22 According to the graph, what is the difference in maximum seismogram height (in mm) between an earthquake of magnitude 4.0 and an earthquake of magnitude 5.0?

23 Look at the shape of the curve on the graph. What does this tell you about the relationship between seismogram heights and earthquake magnitudes? Explain.

Copyright © by Holt, Rinehart and Winston. All rights reserved.



Standardized Test Preparation

EOG Prep

READING

Read each of the passages below. Then, answer the questions that follow each passage.

Passage 1 At 5:04 P.M. on October 14, 1989, life in California's San Francisco Bay area seemed normal. While 62,000 fans filled Candlestick Park to watch the third game of the World Series, other people were rushing home from a day's work. By 5:05 P.M., the area had changed drastically. The area was rocked by the 6.9 magnitude Loma Prieta earthquake, which lasted 20 s and caused 68 deaths, 3,757 injuries, and the destruction of more than 1,000 homes. Considering that the earthquake was of such a high magnitude and that the earthquake happened during rush hour, it is amazing that more people did not die.

1. In the passage, what does the word *drastically* mean?

A continuously
B severely
C gradually
D not at all

2. Which of the following statements about the Loma Prieta earthquake is false?

F The earthquake happened during rush hour.
G The earthquake destroyed more than 1,000 homes.
H The earthquake lasted for 1 min.
I The earthquake had a magnitude of 6.9.

3. Which of the following statements is a fact in the passage?

A Thousands of people were killed in the Loma Prieta earthquake.
B The Loma Prieta earthquake happened during the morning rush hour.
C The Loma Prieta earthquake was a light to moderate earthquake.
D The Loma Prieta earthquake occurred during the 1989 World Series.

Passage 2 In the United States, seismologists use the Modified Mercalli Intensity Scale to measure the intensity of earthquakes. Japanese seismologists, however, use the Shindo scale to measure earthquake intensity. Earthquakes are assigned a number between 1 and 7 on the scale. Shindo 1 indicates a slight earthquake. Such an earthquake is felt by few people, usually people who are sitting. Shindo 7 indicates a severe earthquake. An earthquake that causes great destruction, such as the earthquake that struck Kobe, Japan, in January 1995, would be classified as Shindo 7.

1. In the passage, what does the word *assigned* mean?

A named
B voted
C given
D chosen

2. Which of the following statements about the Shindo scale is true?

F The Shindo scale is used to measure earthquake strength.
G The Shindo scale, which ranges from 1 to 7, is used to rank earthquake intensity.
H The Shindo scale is the same as the Modified Mercalli Intensity Scale.
I Seismologists all over the world use the Shindo scale.

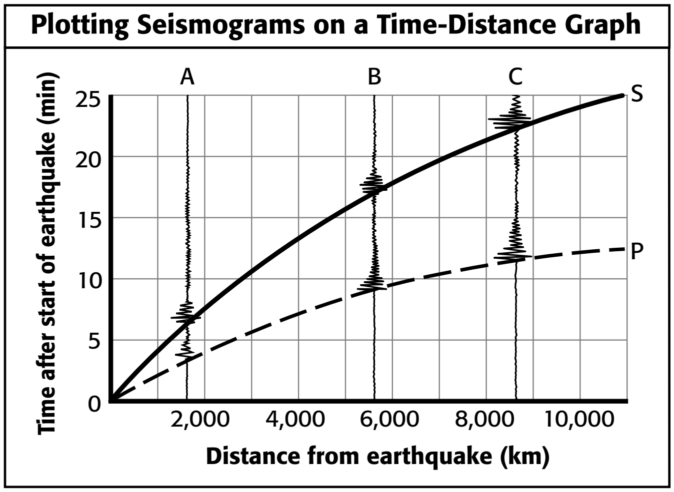
3. Which of the following is a fact in the passage?

A American seismologists use the Richter scale instead of the Shindo scale.
B Japanese seismologists measure the intensity of large earthquakes only.
C The Kobe earthquake was too destructive to be given a Shindo number.
D Shindo 1 indicates a slight earthquake.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

INTERPRETING GRAPHICS

Use the graph below to answer the questions that follow.



1. According to the seismogram, which waves travel the **fastest**?

A P waves travel the fastest.
B S waves travel the fastest.
C P waves and S waves travel at the same speed.
D The graph does not show how fast P waves and S waves travel.

2. What is the approximate difference in minutes between the time the first P waves arrived at station B and the time the first S waves arrived at station B?

F 22 1/2 min
G 10 1/2 min
H 8 min
I 3 min

3. Station A is approximately how much closer to the epicenter than station B is?

A 1,800 km
B 4,000 km
C 5,800 km
D 8,600 km

MATH

Read each question below, and choose the best answer.

1. If a seismic wave travels at a rate of 12 km/s, how far will it travel away from the earthquake in 1 min?

A 7,200 km
B 720 km
C 72 km
D 7.2 km

2. If a P wave travels a distance of 70 km in 10 s, what is its speed?

F 700 km/s
G 70 km/s
H 7 km/s
I 0.7 km/s

3. Each time the magnitude of an earthquake increases by 1 unit, the amount of energy released is 31.7 times greater. How much greater is the energy for a magnitude 7.0 earthquake than a magnitude 5.0 earthquake?

A 31,855 times as strong
B 63.4 times as strong
C 634 times as strong
D 1,005 times as strong

4. An approximate relationship between earthquake magnitude and frequency is that when magnitude increases by 1.0, 10 times fewer earthquakes occur. Thus, if 150 earthquakes of magnitude 2.0 happen in your area this year, about how many 4.0 magnitude earthquakes will happen in your area this year?

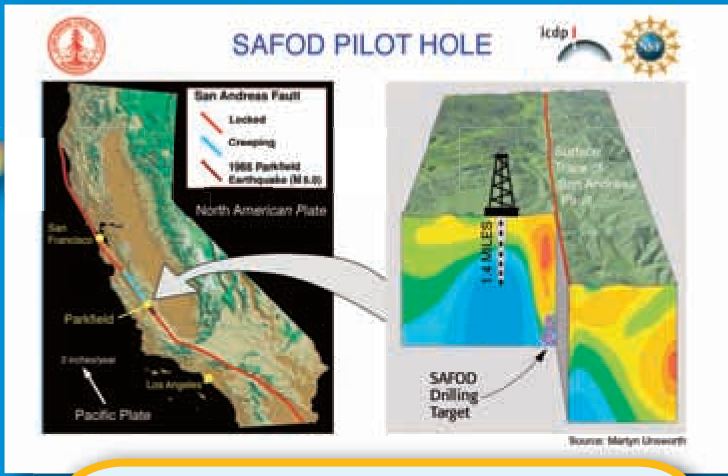
F 50
G 10
H 2
I 0

5. If an average of 421,140 earthquakes occur annually, what percentage of these earthquakes are minor earthquakes if 49,000 minor earthquakes occur annually?

A approximately .01%
B approximately .12%
C approximately 12%
D approximately 86%

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Science in Action



Weird Science

Can Animals Predict Earthquakes?

Is it possible that animals close to the epicenter of an earthquake are able to sense changes in their environment? And should we be paying attention to such animal behavior? As long ago as the 1700s, unusual animal activity prior to earthquakes has been recorded. Examples include domestic cattle seeking higher ground and zoo animals refusing to enter their shelters at night. Other animals, such as lizards, snakes, and small mammals, evacuate their underground burrows, and wild birds leave their usual habitats. These events occur days, hours, or even minutes before an earthquake.

Language Arts ACTIVITY

WRITING SKILL Create an illustrated field guide of animal activity to show how animal activity can predict earthquakes. Each illustration must have a paragraph that describes the activity of a specific animal.

Science, Technology, and Society

San Andreas Fault Observatory at Depth (SAFOD)

Seismologists are creating an underground observatory in Parkfield, California, to study earthquakes along the San Andreas Fault. The observatory will be named the San Andreas Fault Observatory at Depth (SAFOD). A deep hole will be drilled directly into the fault zone near a point where earthquakes of magnitude 6.0 have been recorded. Instruments will be placed at the bottom of the hole, 3 to 4 km beneath Earth's surface. These instruments will make seismological measurements of earthquakes and measure the deformation of rock.

Social Studies ACTIVITY

Research the great San Francisco earthquake of 1906. Find images of the earthquake on the Internet and download them, or cut them out of old magazines. Create a photo collage of the earthquake that shows San Francisco before and after the earthquake.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Hiroo Kanamori

Seismologist Hiroo Kanamori is a seismologist at the California Institute of Technology in Pasadena, California. Dr. Kanamori studies how earthquakes occur and tries to reduce their impact on our society. He also analyzes what the effects of earthquakes on oceans are and how earthquakes create giant ocean waves called *tsunamis* (tsoo NAH meez). Tsunamis are very destructive to life and property when they reach land. Kanamori has discovered that even some weak earthquakes can cause powerful tsunamis. He calls these events *tsunami earthquakes,* and he has learned to predict when tsunamis will form. In short, when tectonic plates grind together slowly, special waves called *long-period seismic waves* are created. When Kanamori sees a long-period wave recorded on a seismogram, he knows a tsunami will form. Because long-period waves travel faster than tsunamis, they arrive at recording stations earlier. When an earthquake station records an earthquake, information about that earthquake is provided to a tsunami warning center. The center determines if the earthquake may cause a tsunami and, if so, issues a tsunami warning to areas that may be affected.

Math Activity

An undersea earthquake causes a tsunami to form. The tsunami travels across the open ocean at 800 km/h. How long will the tsunami take to travel from the point where it formed to a coastline 3,600 km away?

To learn more about these Science in Action topics, visit go.hrw.com and type in the keyword HZ5EQKF.

Current Science

Check out Current Science® articles related to this chapter by visiting go.hrw.com. Just type in the keyword HZ5CS08.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

6

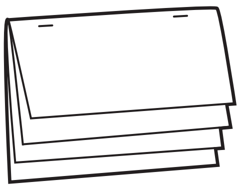
Volcanoes

About the PHOTO

When you think of a volcanic eruption, you probably think of a cone-shaped mountain exploding and sending huge clouds of ash into the air. Some volcanic eruptions do just that! Most volcanic eruptions, such as the one shown here, which is flowing over a road in Hawaii, are slow and quiet. Volcanic eruptions happen throughout the world, and they play a major role in shaping the Earth's surface.

PRE-READING ACTIVITY

FOLDNOTES **Layered Book** Before you read the chapter, create the FoldNote entitled "Layered Book" described in the **Study Skills** section of the Appendix. Label the tabs of the layered book with "Volcanic eruptions," "Effects of eruptions," and "Causes of eruptions." As you read the chapter, write information you learn about each category under the appropriate tab.



Copyright © by Holt, Rinehart and Winston. All rights reserved.

START-UP ACTIVITY

Anticipation

In this activity, you will build a simple model of a volcano and you will try to predict an eruption.

Procedure

1. Place **10 mL of baking soda** on a **sheet of tissue.** Fold the corners of the tissue over the baking soda, and place the tissue packet in a **large pan.**
2. Put **modeling clay** around the top edge of a **funnel.** Press that end of the funnel over the tissue packet to make a tight seal.
3. After you put on **safety goggles,** add **50 mL of vinegar** and **several drops of liquid dish soap** to a **200 mL beaker** and stir.
4. Predict how long it will take the volcano to erupt after the liquid is poured into the funnel. Then, carefully pour the liquid into the funnel, and use a **stopwatch** to measure how long the volcano takes to begin erupting.

Analysis

1. Based on your observations, explain what happened to cause the eruption.
2. How accurate was your prediction? By how many seconds did the class predictions vary?
3. How do the size of the funnel opening and the amount of baking soda and vinegar affect the amount of time that the volcano takes to erupt?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 1

Volcanic Eruptions

Think about the force released when the first atomic bomb exploded during World War II. Now imagine an explosion 10,000 times stronger, and you will get an idea of how powerful a volcanic eruption can be.

READING WARM-UP

Objectives

- Distinguish between nonexplosive and explosive volcanic eruptions.
- Identify the features of a volcano.
- Explain how the composition of magma affects the type of volcanic eruption that will occur.
- Describe four types of lava and four types of pyroclastic material.

Terms to Learn

volcano
vent
magma chamber

READING STRATEGY

Reading Organizer As you read this section, make a table comparing types of lava and pyroclastic material.

The explosive pressure of a volcanic eruption can turn an entire mountain into a billowing cloud of ash and rock in a matter of seconds. But eruptions are also creative forces—they help form fertile farmland. They also create some of the largest mountains on Earth. During an eruption, molten rock, or *magma,* is forced to the Earth's surface. Magma that flows onto the Earth's surface is called *lava*. **Volcanoes** are areas of Earth's surface through which magma and volcanic gases pass.

Nonexplosive Eruptions

At this moment, volcanic eruptions are occurring around the world—on the ocean floor and on land. Nonexplosive eruptions are the most common type of eruption. These eruptions produce relatively calm flows of lava, such as those shown in **Figure 1.** Nonexplosive eruptions can release huge amounts of lava. Vast areas of the Earth's surface, including much of the sea floor and the Northwest region of the United States, are covered with lava from nonexplosive eruptions.

volcano a vent or fissure in the Earth's surface through which magma and gases are expelled

Figure 1 Examples of Nonexplosive Eruptions

Sometimes, nonexplosive eruptions can spray lava into the air. Lava fountains, such as this one, pulse with the pressure of escaping gases.

The speed of a lava flow can range from a slow creep to as fast as 60 km/h.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Explosive Eruptions

Explosive eruptions, such as the one shown in **Figure 2,** are much rarer than nonexplosive eruptions. However, the effects of explosive eruptions can be incredibly destructive. During an explosive eruption, clouds of hot debris, ash, and gas rapidly shoot out from a volcano. Instead of producing lava flows, explosive eruptions cause molten rock to be blown into tiny particles that harden in the air. The dust-sized particles, called *ash,* can reach the upper atmosphere and can circle the Earth for years. Larger pieces of debris fall closer to the volcano. An explosive eruption can also blast millions of tons of lava and rock from a volcano. In a matter of seconds, an explosive eruption can demolish an entire mountainside, as shown in **Figure 3.**

Reading Check **List two differences between explosive and nonexplosive eruptions.** (*See the Appendix for answers to Reading Checks.*)

Figure 2 *In what resembles a nuclear explosion, volcanic ash rockets skyward during the 1990 eruption of Mount Redoubt in Alaska.*

Figure 3 *Within seconds, the 1980 eruption of Mount St. Helens in Washington State caused the side of the mountain to collapse. The blast scorched and flattened 600 km^2 of forest.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

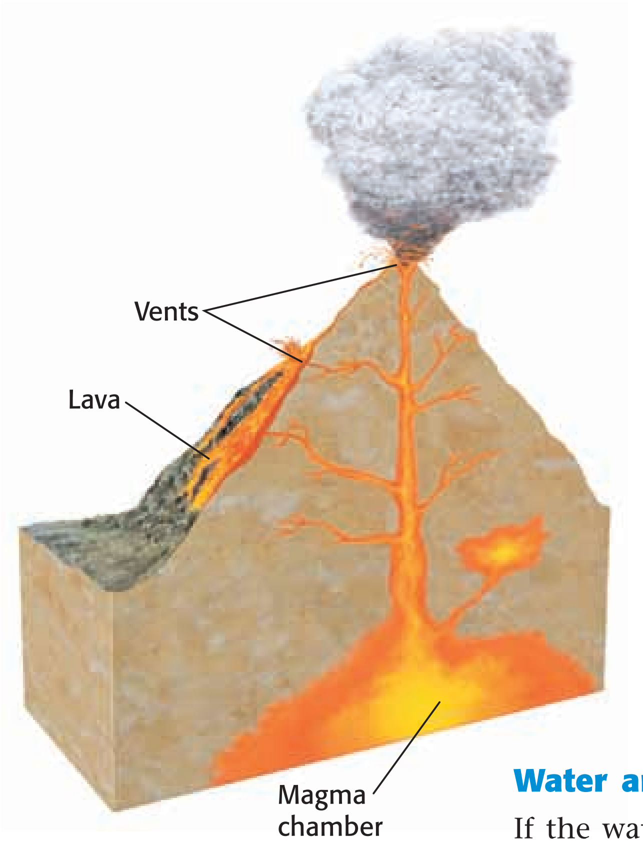


Figure 4 *Volcanoes form when lava is released from vents.*

What Is Inside a Volcano?

If you could look inside an erupting volcano, you would see the features shown in **Figure 4.** A **magma chamber** is a body of molten rock deep underground that feeds a volcano. Magma rises from the magma chamber through cracks in the Earth's crust to openings called **vents.** Magma is released from the vents during an eruption.

magma chamber the body of molten rock that feeds a volcano

vent an opening at the surface of the Earth through which volcanic material passes

What Makes Up Magma?

By comparing the composition of magma from different eruptions, scientists have made an important discovery. The composition of the magma affects how explosive a volcanic eruption is. The key to whether an eruption will be explosive lies in the silica, water, and gas content of the magma.

Water and Magma Are an Explosive Combination

If the water content of magma is high, an explosive eruption is more likely. Because magma is underground, it is under intense pressure and water stays dissolved in the magma. If the magma quickly moves to the surface, the pressure suddenly decreases and the water and other compounds, such as carbon dioxide, become gases. As the gases expand rapidly, an explosion can result. This process is similar to what happens when you shake a can of soda and open it. When a can of soda is shaken, the CO_2 dissolved in the soda is released and pressure builds up. When the can is opened, the soda shoots out, just as lava shoots out of a volcano during an explosive eruption. In fact, some lava is so frothy with gas when it reaches the surface that its solid form, called *pumice,* can float in water!

Silica-Rich Magma Traps Explosive Gases

Magma that has a high silica content also tends to cause explosive eruptions. Silica-rich magma has a stiff consistency. It flows slowly and tends to harden in a volcano's vents. As a result, it plugs the vent. As more magma pushes up from below, pressure increases. If enough pressure builds up, an explosive eruption takes place. Stiff magma also prevents water vapor and other gases from easily escaping. Gas bubbles trapped in magma can expand until they explode. When they explode, the magma shatters and ash and pumice are blasted from the vent. Magma that contains less silica has a more fluid, runnier consistency. Because gases escape this type of magma more easily, explosive eruptions are less likely to occur.

Reading Check **How do silica levels affect an eruption?**

Copyright © by Holt, Rinehart and Winston. All rights reserved.

What Erupts from a Volcano?

Magma erupts as either lava or pyroclastic (PIE roh KLAS tik) material. *Lava* is liquid magma that flows from a volcanic vent. *Pyroclastic material* forms when magma is blasted into the air and hardens. Nonexplosive eruptions produce mostly lava. Explosive eruptions produce mostly pyroclastic material. Over many years—or even during the same eruption—a volcano's eruptions may alternate between lava and pyroclastic eruptions.

Types of Lava

The viscosity of lava, or how lava flows, varies greatly. To understand viscosity, remember that a milkshake has high viscosity and a glass of milk has low viscosity. Lava that has high viscosity is stiff. Lava that has low viscosity is more fluid. The viscosity of lava affects the surface of a lava flow in different ways, as shown in **Figure 5.** *Blocky lava* and *pahoehoe* (puh HOY HOY) have a high viscosity and flow slowly. Other types of lava flows, such as *aa* (AH AH) and *pillow lava,* have lower viscosities and flow more quickly.

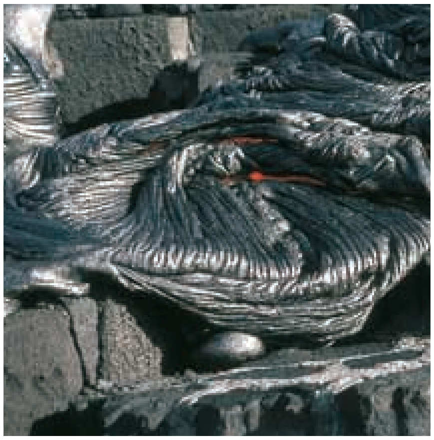
CONNECTION TO Social Studies

Fertile Farmlands Volcanic ash helps create some of the most fertile farmland in the world. Use a world map and reference materials to find the location of volcanoes that have helped create farmland in Italy, Africa, South America, and the United States. Make an illustrated map on a piece of poster board to share your findings.

ACTIVITY

Figure 5 **Four Types of Lava**

Aa is so named because of the painful experience of walking barefoot across its jagged surface. This lava pours out quickly and forms a brittle crust. The crust is torn into jagged pieces as molten lava continues to flow underneath.



Pahoehoe lava flows slowly, like wax dripping from a candle. Its glassy surface has rounded wrinkles.

Pillow lava forms when lava erupts underwater. As you can see here, this lava forms rounded lumps that are the shape of pillows.

Blocky lava is cool, stiff lava that does not travel far from the erupting vent. Blocky lava usually oozes from a volcano and forms jumbled heaps of sharp-edged chunks.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 6 **Four Types of Pyroclastic Material**

Volcanic bombs are large blobs of magma that harden in the air. The shape of this bomb was caused by the magma spinning through the air as it cooled.

Lapilli, which means "little stones" in Italian, are pebblelike bits of magma that hardened before they hit the ground.

Volcanic ash forms when the gases in stiff magma expand rapidly and the walls of the gas bubbles explode into tiny, glasslike slivers. Ash makes up most of the pyroclastic material in an eruption.

Volcanic blocks, the largest pieces of pyroclastic material, are pieces of solid rock erupted from a volcano.

Types of Pyroclastic Material

Pyroclastic material forms when magma explodes from a volcano and solidifies in the air. This material also forms when powerful eruptions shatter existing rock. The size of pyroclastic material ranges from boulders that are the size of houses to tiny particles that can remain suspended in the atmosphere for years. **Figure 6** shows four types of pyroclastic material: volcanic bombs, volcanic blocks, lapilli (lah PIL IE), and volcanic ash.

✓ *Reading Check* **Describe four types of pyroclastic material.**

Quick Lab

Modeling an Explosive Eruption

1. Inflate a **large balloon,** and place it in a **cardboard box.**
2. Spread a **sheet** on the floor. Place the box in the middle of the sheet. Mound a thin layer of **sand** over the balloon to make a volcano that is taller than the edges of the box.
3. Lightly mist the volcano with **water.** Sprinkle **tempera paint** on the volcano until the volcano is completely covered.
4. Place **small objects** such as **raisins** randomly on the volcano. Draw a sketch of the volcano.
5. Put on your **safety goggles.** Pop the balloon with a **pin.**
6. Use a **metric ruler** to calculate the average distance that 10 grains of sand and 10 raisins traveled.
7. How did the relative weight of each type of material affect the average distance that the material traveled?
8. Draw a sketch of the exploded volcano.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Pyroclastic Flows

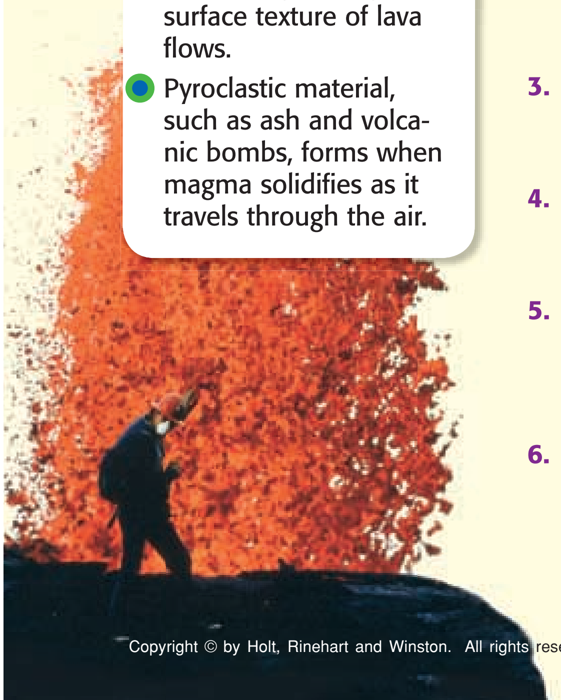
One particularly dangerous type of volcanic flow is called a *pyroclastic flow*. Pyroclastic flows are produced when enormous amounts of hot ash, dust, and gases are ejected from a volcano. This glowing cloud of pyroclastic material can race downhill at speeds of more than 200 km/h—faster than most hurricane-force winds! The temperature at the center of a pyroclastic flow can exceed 700°C. A pyroclastic flow from the eruption of Mount Pinatubo is shown in **Figure 7.** Fortunately, scientists were able to predict the eruption and a quarter of a million people were evacuated before the eruption.

Figure 7 *The 1991 eruption of Mount Pinatubo in the Philippines released terrifying pyroclastic flows.*

SECTION Review

Summary

- Volcanoes erupt both explosively and nonexplosively.
- Magma that has a high level of water, CO_2, or silica tends to erupt explosively.
- Lava can be classified by its viscosity and by the surface texture of lava flows.
- Pyroclastic material, such as ash and volcanic bombs, forms when magma solidifies as it travels through the air.



Using Key Terms

1. In your own words, write a definition for each of the following terms: *volcano, magma chamber,* and *vent.*

Understanding Key Ideas

2. Which of the following factors influences whether a volcano erupts explosively?
   a. the concentration of volcanic bombs in the magma
   b. the concentration of phosphorus in the magma
   c. the concentration of aa in the magma
   d. the concentration of water in the magma
3. How are lava and pyroclastic material classified? Describe four types of lava.
4. Which produces more pyroclastic material: an explosive eruption or a nonexplosive eruption?
5. Explain how the presence of silica and water in magma increases the chances of an explosive eruption.
6. What is a pyroclastic flow?

Math Skills

7. A sample of magma is 64% silica. Express this percentage as a simplified fraction.

Critical Thinking

8. **Analyzing Ideas** How is an explosive eruption similar to opening a can of soda that has been shaken? Be sure to describe the role of carbon dioxide.
9. **Making Inferences** Predict the silica content of aa, pillow lava, and blocky lava.
10. **Making Inferences** Explain why the names of many types of lava are Hawaiian but the names of many types of pyroclastic material are Italian and Indonesian.

SCILINKS. NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Volcanic Eruptions
SciLinks code: HSM1616

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 2

Effects of Volcanic Eruptions

In 1816, Chauncey Jerome, a resident of Connecticut, wrote that the clothes his wife had laid out to dry the day before had frozen during the night. This event would not have been unusual except that the date was June 10!

At that time, residents of New England did not know that the explosion of a volcanic island on the other side of the world had severely changed the global climate and was causing "The Year Without a Summer."

READING WARM-UP

Objectives

- Explain how volcanic eruptions can affect climate.
- Compare the three types of volcanoes.
- Compare craters, calderas, and lava plateaus.

Terms to Learn

crater
caldera
lava plateau

READING STRATEGY

Paired Summarizing Read this section silently. In pairs, take turns summarizing the material. Stop to discuss ideas that seem confusing.

Volcanic Eruptions and Climate Change

The explosion of Mount Tambora in 1815 blanketed most of Indonesia in darkness for three days. It is estimated that 12,000 people died directly from the explosion and 80,000 people died from the resulting hunger and disease. The global effects of the eruption were not felt until the next year, however. During large-scale eruptions, enormous amounts of volcanic ash and gases are ejected into the upper atmosphere.

As volcanic ash and gases spread throughout the atmosphere, they can block enough sunlight to cause global temperatures to drop. The Tambora eruption affected the global climate enough to cause food shortages in North America and Europe. More recently, the eruption of Mount Pinatubo, shown in **Figure 1,** caused average global temperatures to drop by as much as 0.5°C. Although this may seem insignificant, such a shift can disrupt climates all over the world.

Reading Check How does a volcanic eruption affect climate? *(See the Appendix for answers to Reading Checks.)*

Figure 1 *Ash from the eruption of Mount Pinatubo blocked out the sun in the Philippines for several days. The eruption also affected global climate.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Different Types of Volcanoes

Volcanic eruptions can cause profound changes in climate. But the changes to Earth's surface caused by eruptions are probably more familiar. Perhaps the best known of all volcanic landforms are the volcanoes themselves. The three basic types of volcanoes are illustrated in **Figure 2.**

Shield Volcanoes

Shield volcanoes are built of layers of lava released from repeated nonexplosive eruptions. Because the lava is very runny, it spreads out over a wide area. Over time, the layers of lava create a volcano that has gently sloping sides. Although their sides are not very steep, shield volcanoes can be enormous. Hawaii's Mauna Kea, the shield volcano shown here, is the tallest mountain on Earth. Measured from its base on the sea floor, Mauna Kea is taller than Mount Everest.

Cinder Cone Volcanoes

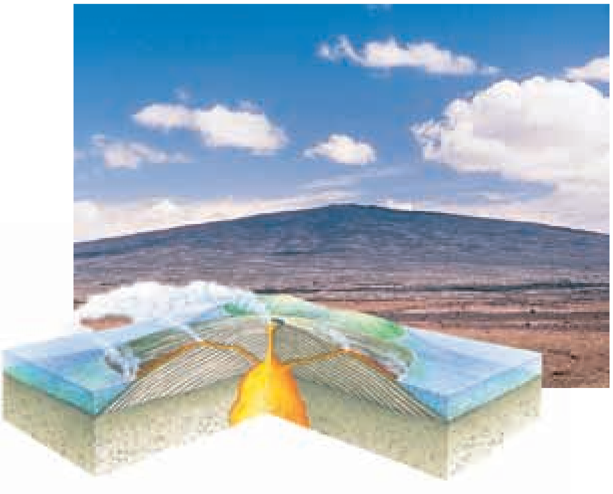
Cinder cone volcanoes are made of pyroclastic material usually produced from moderately explosive eruptions. The pyroclastic material forms steep slopes, as shown in this photo of the Mexican volcano Paricutín. Cinder cones are small and usually erupt for only a short time. Paricutín appeared in a cornfield in 1943 and erupted for only nine years before stopping at a height of 400 m. Cinder cones often occur in clusters, commonly on the sides of other volcanoes. They usually erode quickly because the pyroclastic material is not cemented together.

Composite Volcanoes

Composite volcanoes, sometimes called *stratovolcanoes,* are one of the most common types of volcanoes. They form from explosive eruptions of pyroclastic material followed by quieter flows of lava. The combination of both types of eruptions forms alternating layers of pyroclastic material and lava. Composite volcanoes, such as Japan's Mount Fuji (shown here), have broad bases and sides that get steeper toward the top. Composite volcanoes in the western region of the United States include Mount Hood, Mount Rainier, Mount Shasta, and Mount St. Helens.

Figure 2 **Three Types of Volcanoes**

Shield volcano



Cinder cone volcano

Composite volcano

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 3 *A crater, such as this one in Kamchatka, Russia, forms around the central vent of a volcano.*

Other Types of Volcanic Landforms

In addition to volcanoes, other landforms are produced by volcanic activity. These landforms include craters, calderas, and lava plateaus. Read on to learn more about these landforms.

Craters

Around the central vent at the top of many volcanoes is a funnel-shaped pit called a **crater.** An example of a crater is shown in **Figure 3.** During less explosive eruptions, lava flows and pyroclastic material can pile up around the vent creating a cone with a central crater. As the eruption stops, the lava that is left in the crater often drains back underground. The vent may then collapse to form a larger crater. If the lava hardens in the crater, the next eruption may blast it away. In this way, a crater becomes larger and deeper.

crater a funnel-shaped pit near the top of the central vent of a volcano

caldera a large, semicircular depression that forms when the magma chamber below a volcano partially empties and causes the ground above to sink

Calderas

Calderas can appear similar to craters, but they are many times larger. A **caldera** is a large, semicircular depression that forms when the chamber that supplies magma to a volcano partially empties and the chamber's roof collapses. As a result, the ground above the magma chamber sinks, as shown in **Figure 4.** Much of Yellowstone Park is made up of three large calderas that formed when volcanoes collapsed between 1.9 million and 0.6 million years ago. Today, hot springs, such as Old Faithful, are heated by the thermal energy left over from those events.

Reading Check **How do calderas form?**

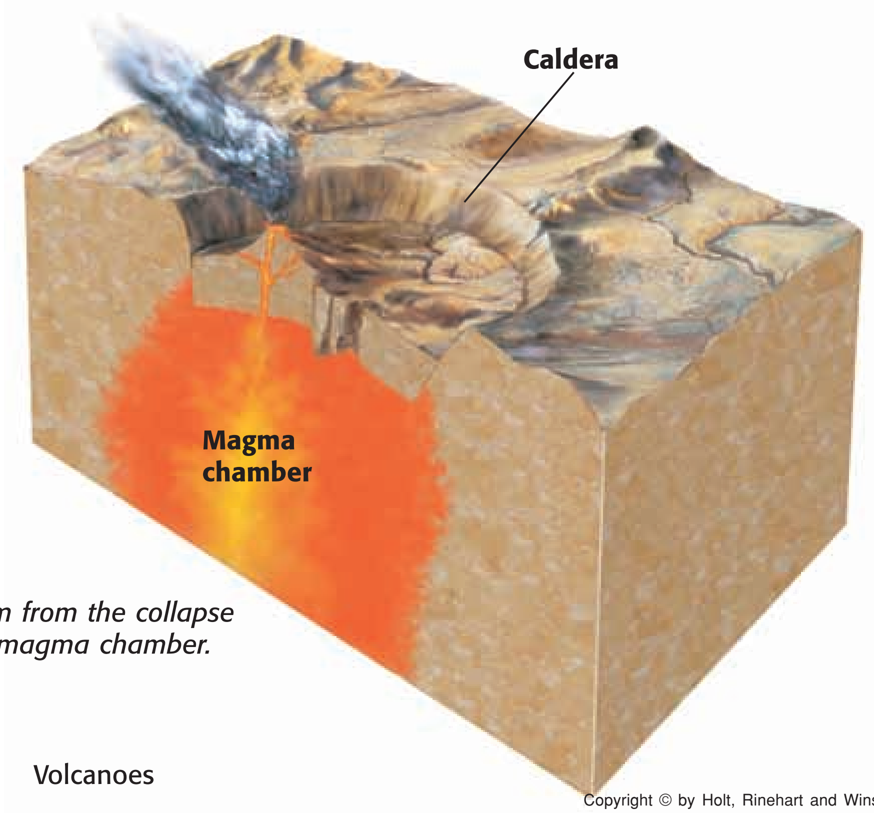


Figure 4 *Calderas form from the collapse of the roof overlying a magma chamber.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 5 *The Columbia River Plateau formed from a massive outpouring of lava that began 17 million years ago.*

Lava Plateaus

The most massive outpourings of lava do not come from individual volcanoes. Most of the lava on Earth's surface erupted from long cracks, or *rifts,* in the crust. In this type of eruption, runny lava can pour out for millions of years and spread over huge areas. A landform that results from repeated eruptions of lava spread over a large area is called a **lava plateau.** The Columbia River Plateau, part of which is shown in **Figure 5,** is a lava plateau that formed between 17 million and 14 million years ago in the northwestern region of the United States. In some places, the Columbia River Plateau is 3 km thick.

lava plateau a wide, flat landform that results from repeated nonexplosive eruptions of lava that spread over a large area

SECTION Review

Summary

- The large volumes of gas and ash released from volcanic eruptions can affect climate.
- Shield volcanoes result from many eruptions of relatively runny lava.
- Cinder cone volcanoes result from mildly explosive eruptions of pyroclastic material.
- Composite volcanoes result from alternating explosive and nonexplosive eruptions.
- Craters, calderas, and lava plateaus are volcanic landforms.

Using Key Terms

Complete each of the following sentences by choosing the correct term from the word bank.

caldera crater

1. A ___ is a funnel-shaped hole around the central vent.
2. A ___ results when a magma chamber partially empties.

Understanding Key Ideas

3. Which type of volcano results from alternating explosive and nonexplosive eruptions?
   - **a.** composite volcano
   - **b.** cinder cone volcano
   - **c.** rift-zone volcano
   - **d.** shield volcano
4. Why do cinder cone volcanoes have narrower bases and steeper sides than shield volcanoes do?
5. Why does a volcano's crater tend to get larger over time?

Math Skills

6. The fastest lava flow recorded was 60 km/h. A horse can gallop as fast as 48 mi/h. Could a galloping horse outrun the fastest lava flow? (Hint: 1 km = 0.621 mi)

Critical Thinking

7. **Making Inferences** Why did it take a year for the effects of the Tambora eruption to be experienced in New England?

SCILINKS® NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Volcanic Effects
SciLinks code: HSM1615

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 3

Causes of Volcanic Eruptions

More than 2,000 years ago, Pompeii was a busy Roman city near the sleeping volcano Mount Vesuvius. People did not see Vesuvius as much of a threat. Everything changed when Vesuvius suddenly erupted and buried the city in a deadly blanket of ash that was almost 20 ft thick!

Today, even more people are living on and near active volcanoes. Scientists closely monitor volcanoes to avoid this type of disaster. They study the gases coming from active volcanoes and look for slight changes in the volcano's shape that could indicate that an eruption is near. Scientists know much more about the causes of eruptions than the ancient Pompeiians did, but there is much more to be discovered.

READING WARM-UP

Objectives

- Describe the formation and movement of magma.
- Explain the relationship between volcanoes and plate tectonics.
- Summarize the methods scientists use to predict volcanic eruptions.

Terms to Learn

rift zone
hot spot

READING STRATEGY

Reading Organizer As you read this section, make a flowchart of the steps of magma formation in different tectonic environments.

The Formation of Magma

Understanding how magma forms helps explain why volcanoes erupt. Magma forms in the deeper regions of the Earth's crust and in the uppermost layers of the mantle where the temperature and pressure are very high. Changes in pressure and temperature cause magma to form.

Pressure and Temperature

Part of the upper mantle is made of very hot, puttylike rock that flows slowly. The rock of the mantle is hot enough to melt at Earth's surface, but it remains a puttylike solid because of pressure. This pressure is caused by the weight of the rock above the mantle. In other words, the rock above the mantle presses the atoms of the mantle so close together that the rock cannot melt. As **Figure 1** shows, rock melts when its temperature increases or when the pressure on the rock decreases.

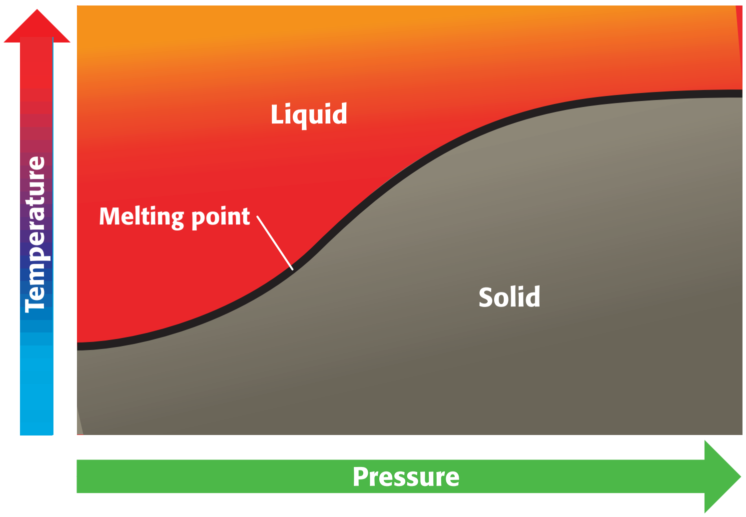


Figure 1 *The curved line indicates the melting point of a rock. As pressure decreases and temperature increases, the rock begins to melt.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Magma Formation in the Mantle

Because the temperature of the mantle is fairly constant, a decrease in pressure is the most common cause of magma formation. Magma often forms at the boundary between separating tectonic plates, where pressure is decreased. Once formed, the magma is less dense than the surrounding rock, so the magma slowly rises toward the surface like an air bubble in a jar of honey.

Where Volcanoes Form

The locations of volcanoes give clues about how volcanoes form. The map in **Figure 2** shows the location of some of the world's major active volcanoes. The map also shows the boundaries between tectonic plates. A large number of volcanoes lie directly on tectonic plate boundaries. In fact, the plate boundaries surrounding the Pacific Ocean have so many volcanoes that the area is called the *Ring of Fire*.

Tectonic plate boundaries are areas where tectonic plates either collide, separate, or slide past one another. At these boundaries, it is possible for magma to form and travel to the surface. About 80% of active volcanoes on land form where plates collide, and about 15% form where plates separate. The remaining few occur far from tectonic plate boundaries.

Reading Check **Why are most volcanoes on plate boundaries?** (*See the Appendix for answers to Reading Checks.*)

Quick Lab

Reaction to Stress

1. Make a pliable "rock" by pouring **60 mL of water** into a **plastic cup** and adding **150 mL of cornstarch,** 15 mL at a time. Stir well each time.
2. Pour half of the cornstarch mixture into a **clear bowl.** Carefully observe how the "rock" flows. Be patient—this process is slow!
3. Scrape the rest of the "rock" out of the cup with a **spoon.** Observe the behavior of the "rock" as you scrape.
4. What happened to the "rock" when you let it flow by itself? What happened when you put stress on the "rock"?
5. How is this pliable "rock" similar to the rock of the upper part of the mantle?

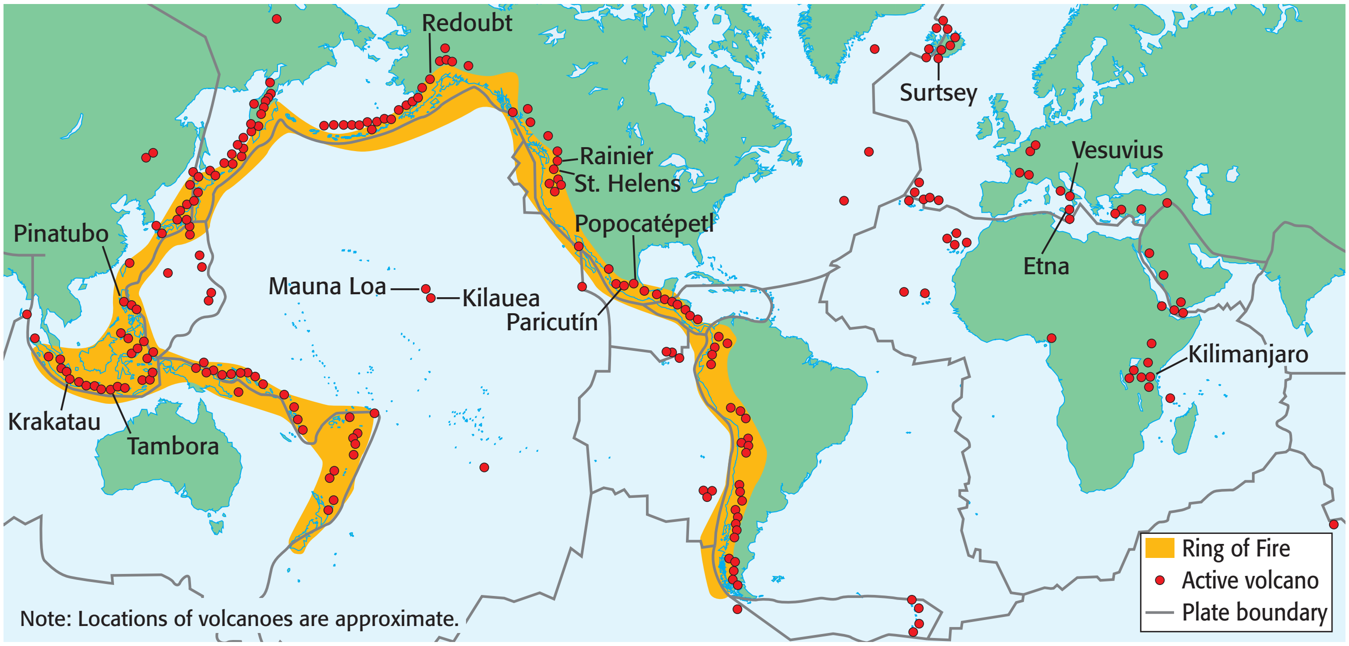


Figure 2 *Tectonic plate boundaries are likely places for volcanoes to form. The Ring of Fire contains nearly 75% of the world's active volcanoes on land.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

When Tectonic Plates Separate

At a *divergent boundary,* tectonic plates move away from each other. As tectonic plates separate, a set of deep cracks called a **rift zone** forms between the plates. Mantle rock then rises to fill in the gap. When mantle rock gets closer to the surface, the pressure decreases. The pressure decrease causes the mantle rock to melt and form magma. Because magma is less dense than the surrounding rock, it rises through the rifts. When the magma reaches the surface, it spills out and hardens, creating new crust, as shown in **Figure 3.**

MATH PRACTICE

How Hot Is Hot?

Inside the Earth, magma can reach a burning-hot 1,400°C! You may be more familiar with Fahrenheit temperatures, so convert 1,400°C to degrees Fahrenheit by using the formula below.

$$°F = (°C \div 5 \times 9) + 32$$

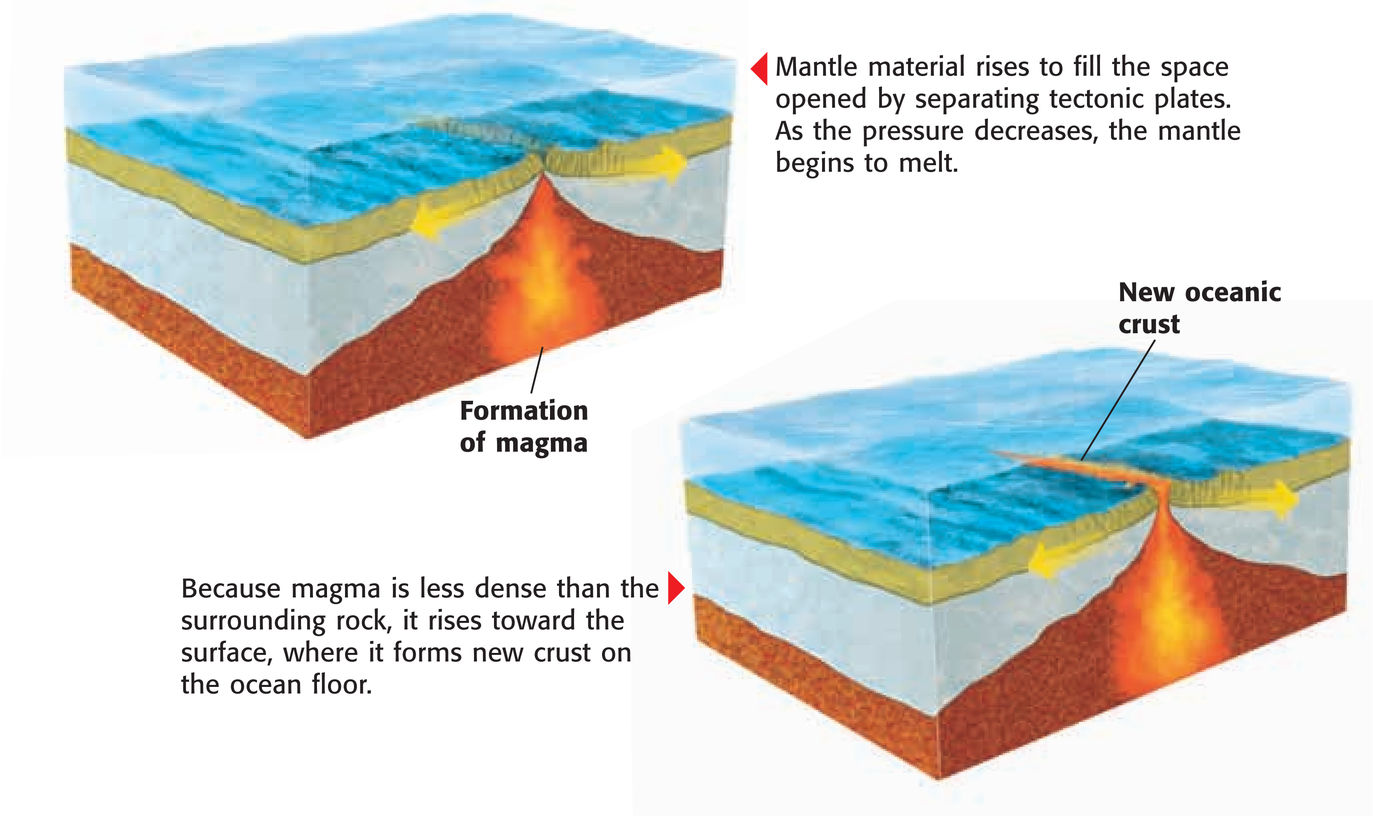
What is the temperature in degrees Fahrenheit?

rift zone an area of deep cracks that forms between two tectonic plates that are pulling away from each other

Mid-Ocean Ridges Form at Divergent Boundaries

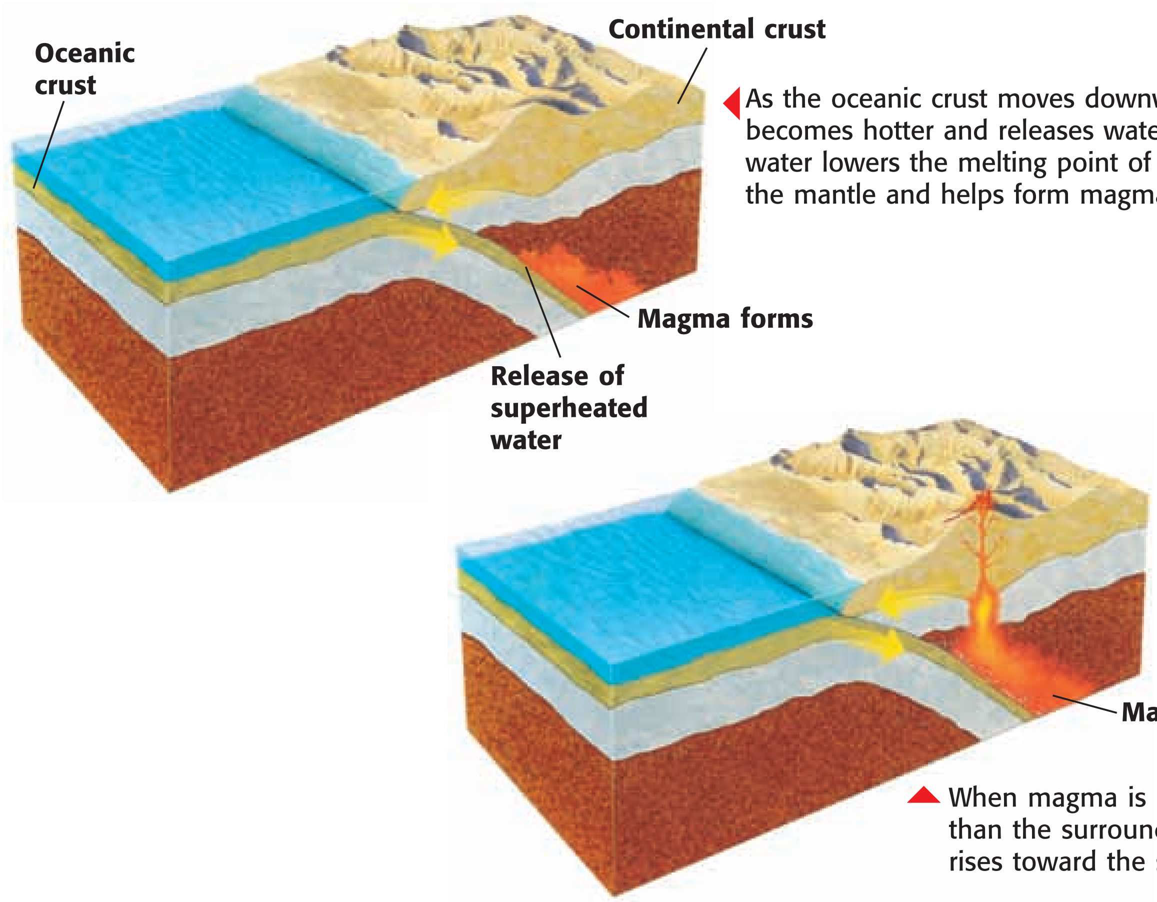
Lava that flows from undersea rift zones produces volcanoes and mountain chains called *mid-ocean ridges*. Just as a baseball has stitches, the Earth is circled with mid-ocean ridges. At these ridges, lava flows out and creates new crust. Most volcanic activity on Earth occurs at mid-ocean ridges. While most mid-ocean ridges are underwater, Iceland, with its volcanoes and hot springs, was created by lava from the Mid-Atlantic Ridge. In 1963, enough lava poured out of the Mid-Atlantic Ridge near Iceland to form a new island called *Surtsey*. Scientists watched this new island being born!

Figure 3 **How Magma Forms at a Divergent Boundary**



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 4 **How Magma Forms at a Convergent Boundary**



When Tectonic Plates Collide

If you slide two pieces of notebook paper into one another on a flat desktop, the papers will either buckle upward or one piece of paper will move under the other. This is similar to what happens at a convergent boundary. A *convergent boundary* is a place where tectonic plates collide. When an oceanic plate collides with a continental plate, the oceanic plate usually slides underneath the continental plate. The process of *subduction,* the movement of one tectonic plate underneath another, is shown in **Figure 4.** Oceanic crust is subducted because it is denser and thinner than continental crust.

Subduction Produces Magma

As the descending oceanic crust scrapes past the continental crust, the temperature and pressure increase. The combination of increased heat and pressure causes the water contained in the oceanic crust to be released. The water then mixes with the mantle rock, which lowers the rock's melting point, causing it to melt. This body of magma can rise to form a volcano.

Reading Check **How does subduction produce magma?**

SCHOOL to HOME

Tectonic Models

Create models of convergent and divergent boundaries by using materials of your choice. Have your teacher approve your list before you start building your model at home with a parent. In class, use your model to explain how each type of boundary leads to the formation of magma.

ACTIVITY

Copyright © by Holt, Rinehart and Winston. All rights reserved.

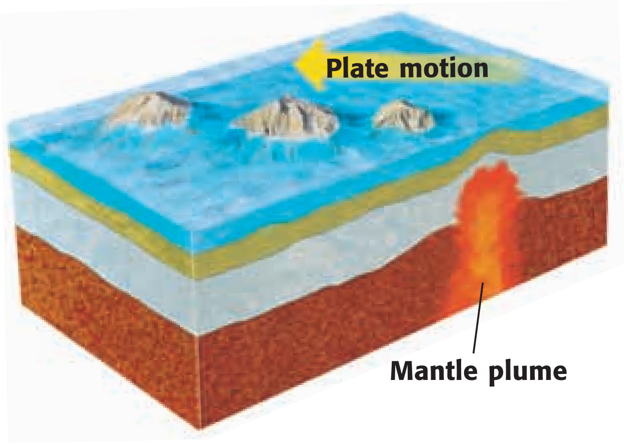


Figure 5 *According to one theory, a string of volcanic islands forms as a tectonic plate passes over a mantle plume.*

Hot Spots

Not all magma develops along tectonic plate boundaries. For example, the Hawaiian Islands, some of the most well-known volcanoes on Earth, are nowhere near a plate boundary. The volcanoes of Hawaii and several other places on Earth are known as *hot spots*. **Hot spots** are volcanically active places on the Earth's surface that are far from plate boundaries. Some scientists think that hot spots are directly above columns of rising magma, called *mantle plumes*. Other scientists think that hot spots are the result of cracks in the Earth's crust.

A hot spot often produces a long chain of volcanoes. One theory is that the mantle plume stays in the same spot while the tectonic plate moves over it, as shown in **Figure 5.** Another theory argues that hot-spot volcanoes occur in long chains because they form along the cracks in the Earth's crust. Both theories may be correct.

hot spot a volcanically active area of Earth's surface far from a tectonic plate boundary

Reading Check **Describe two theories that explain the existence of hot spots.**

Predicting Volcanic Eruptions

You now understand some of the processes that produce volcanoes, but how do scientists predict when a volcano is going to erupt? Volcanoes are classified in three categories. *Extinct volcanoes* have not erupted in recorded history and probably never will erupt again. *Dormant volcanoes* are currently not erupting, but the record of past eruptions suggests that they may erupt again. *Active volcanoes* are currently erupting or show signs of erupting in the near future. Scientists study active and dormant volcanoes for signs of a future eruption.

Figure 6 *As if being this close to an active volcano is not dangerous enough, the gases being collected are extremely poisonous.*

Measuring Small Quakes and Volcanic Gases

Most active volcanoes produce small earthquakes as the magma within them moves upward and causes the surrounding rock to shift. Just before an eruption, the number and intensity of the earthquakes increase and the occurrence of quakes may be continuous. Monitoring these quakes is one of the best ways to predict an eruption.

As **Figure 6** shows, scientists also study the volume and composition of volcanic gases. The ratio of certain gases, especially that of sulfur dioxide, SO_2, to carbon dioxide, CO_2, may be important in predicting eruptions. Changes in this ratio may indicate changes in the magma chamber below.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Measuring Slope and Temperature

As magma moves upward prior to an eruption, it can cause the Earth's surface to swell. The side of a volcano may even bulge as the magma moves upward. An instrument called a *tiltmeter* helps scientists detect small changes in the angle of a volcano's slope. Scientists also use satellite technology such as the Global Positioning System (GPS) to detect the changes in a volcano's slope that may signal an eruption.

One of the newest methods for predicting volcanic eruptions includes using satellite images. Infrared satellite images record changes in the surface temperature and gas emissions of a volcano over time. If the site is getting hotter, the magma below is probably rising!

INTERNET ACTIVITY

For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HZ5VOLW.**

SECTION Review

Summary

- Temperature and pressure influence magma formation.
- Most volcanoes form at tectonic boundaries.
- As tectonic plates separate, magma rises to fill the cracks, or rifts, that develop.
- As oceanic and continental plates collide, the oceanic plate tends to subduct and cause the formation of magma.
- To predict eruptions, scientists study the frequency and type of earthquakes associated with the volcano as well as changes in slope, changes in the gases released, and changes in the volcano's surface temperature.

Using Key Terms

1. Use each of the following terms in a separate sentence: *hot spot* and *rift zone*.

Understanding Key Ideas

2. If the temperature of a rock remains constant but the pressure on the rock decreases, what tends to happen?
   a. The temperature increases.
   b. The rock becomes liquid.
   c. The rock becomes solid.
   d. The rock subducts.
3. Which of the following words is a synonym for *dormant*?
   a. predictable
   b. active
   c. dead
   d. sleeping
4. What is the Ring of Fire?
5. Explain how convergent and divergent plate boundaries cause magma formation.
6. Describe four methods that scientists use to predict volcanic eruptions.
7. Why does a oceanic plate tend to subduct when it collides with a continental plate?

Math Skills

8. If a tectonic plate moves at a rate of 2 km every 1 million years, how long would it take a hot spot to form a chain of volcanoes 100 km long?

Critical Thinking

9. **Making Inferences** New crust is constantly being created at mid-ocean ridges. So, why is the oldest oceanic crust only about 150 million years old?
10. **Identifying Relationships** If you are studying a volcanic deposit, would the youngest layers be more likely to be found on the top or on the bottom? Explain your answer.

SCILINKS® NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: What Causes Volcanoes?
SciLinks code: HSM1654

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Skills Practice Lab

Volcano Verdict

OBJECTIVES

Build a working apparatus to test carbon dioxide levels.

Test the levels of carbon dioxide emitted from a model volcano.

MATERIALS

- baking soda, 15 mL
- bottle, drinking, 16 oz
- box or stand for plastic cup
- clay, modeling
- coin
- cup, clear plastic, 9 oz
- graduated cylinder
- limewater, 1 L
- straw, drinking, flexible
- tissue, bathroom (2 sheets)
- vinegar, white, 140 mL
- water, 100 mL

SAFETY

You will need to pair up with a partner for this exploration. You and your partner will act as geologists who work in a city located near a volcano. City officials are counting on you to predict when the volcano will erupt next. You and your partner have decided to use limewater as a gas-emissions tester. You will use this tester to measure the levels of carbon dioxide emitted from a simulated volcano. The more active the volcano is, the more carbon dioxide it releases.

Procedure

1. Put on your safety goggles, and carefully pour limewater into the plastic cup until the cup is three-fourths full. You have just made your gas-emissions tester.
2. Now, build a model volcano. Begin by pouring 50 mL of water and 70 mL of vinegar into the drink bottle.
3. Form a plug of clay around the short end of the straw, as shown at left. The clay plug must be large enough to cover the opening of the bottle. Be careful not to get the clay wet.
4. Sprinkle 5 mL of baking soda along the center of a single section of bathroom tissue. Then, roll the tissue, and twist the ends so that the baking soda can't fall out.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

5. Drop the tissue into the drink bottle, and immediately put the short end of the straw inside the bottle to make a seal with the clay.
6. Put the other end of the straw into the limewater, as shown at right.
7. You have just taken your first measurement of gas levels from the volcano. Record your observations.
8. Imagine that it is several days later and you need to test the volcano again to collect more data. Before you continue, toss a coin. If it lands heads up, go to step 9. If it lands tails up, go to step 10. Write down the step that you follow.
9. Repeat steps 1–7. This time, add 2 mL of baking soda to the vinegar and water. (Note: You must use fresh water, vinegar, and limewater.) Write down your observations. Go to step 11.
10. Repeat steps 1–7. This time, add 8 mL of baking soda to the vinegar and water. (Note: You must use fresh water, vinegar, and limewater.) Write down your observations. Go to step 11.
11. Return to step 8 once. Then, answer the questions below.

Analyze the Results

1. **Explaining Events** How do you explain the difference in the appearance of the limewater from one trial to the next?
2. **Recognizing Patterns** What does the data that you collected indicate about the activity in the volcano?

Draw Conclusions

3. **Evaluating Results** Based on your results, do you think it would be necessary to evacuate the city?
4. **Applying Conclusions** How would a geologist use a gas-emissions tester to predict volcanic eruptions?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Chapter Review

USING KEY TERMS

For each pair of terms, explain how the meanings of the terms differ.

1. *caldera* and *crater*
2. *lava* and *magma*
3. *lava* and *pyroclastic material*
4. *vent* and *rift*
5. *cinder cone volcano* and *shield volcano*

UNDERSTANDING KEY IDEAS

Multiple Choice

6. The type of magma that tends to cause explosive eruptions has a
   a. high silica content and high viscosity.
   b. high silica content and low viscosity.
   c. low silica content and low viscosity.
   d. low silica content and high viscosity.

7. Lava that flows slowly to form a glassy surface with rounded wrinkles is called
   a. aa lava.
   b. pahoehoe lava.
   c. pillow lava.
   d. blocky lava.

8. Magma forms within the mantle most often as a result of
   a. high temperature and high pressure.
   b. high temperature and low pressure.
   c. low temperature and high pressure.
   d. low temperature and low pressure.

9. What causes an increase in the number and intensity of small earthquakes before an eruption?
   a. the movement of magma
   b. the formation of pyroclastic material
   c. the hardening of magma
   d. the movement of tectonic plates

10. If volcanic dust and ash remain in the atmosphere for months or years, what do you predict will happen?
    a. Solar reflection will decrease, and temperatures will increase.
    b. Solar reflection will increase, and temperatures will increase.
    c. Solar reflection will decrease, and temperatures will decrease.
    d. Solar reflection will increase, and temperatures will decrease.

11. At divergent plate boundaries,
    a. heat from Earth's core causes mantle plumes.
    b. oceanic plates sink, which causes magma to form.
    c. tectonic plates move apart.
    d. hot spots cause volcanoes.

12. A theory that helps explain the causes of both earthquakes and volcanoes is the theory of
    a. pyroclastics.
    b. plate tectonics.
    c. climatic fluctuation.
    d. mantle plumes.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Short Answer

13. How does the presence of water in magma affect a volcanic eruption?

14. Describe four clues that scientists use to predict eruptions.

15. Identify the characteristics of the three types of volcanoes.

16. Describe the positive effects of volcanic eruptions.

CRITICAL THINKING

17. **Concept Mapping** Use the following terms to create a concept map: *volcanic bombs, aa, pyroclastic material, pahoehoe, lapilli, lava,* and *volcano.*

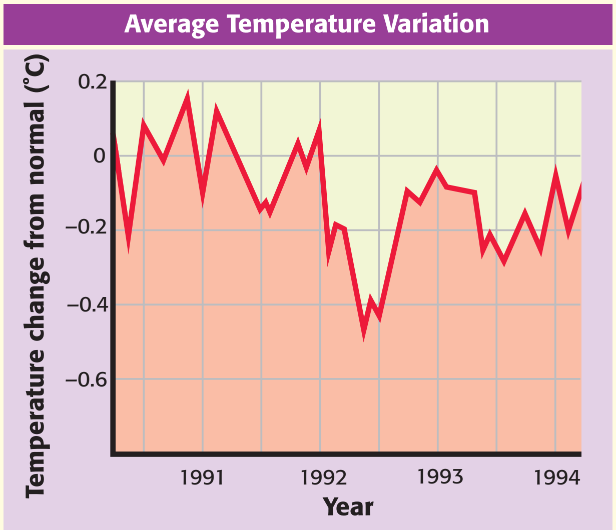
18. **Identifying Relationships** You are exploring a volcano that has been dormant for some time. You begin to keep notes on the types of volcanic debris that you see as you walk. Your first notes describe volcanic ash. Later, your notes describe lapilli. In what direction are you most likely traveling—toward the crater or away from the crater? Explain your answer.

19. **Making Inferences** Loihi is a submarine Hawaiian volcano that might grow to form a new island. The Hawaiian Islands are located on the Pacific plate, which is moving northwest. Considering how this island chain may have formed, where do you think the new volcanic island will be located? Explain your answer.

20. **Evaluating Hypotheses** What evidence could confirm the existence of mantle plumes?

INTERPRETING GRAPHICS

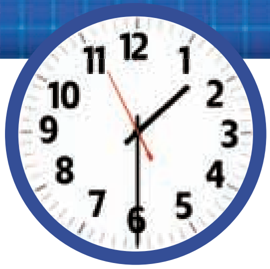
The graph below illustrates the average change in temperature above or below normal for a community over several years. Use the graph below to answer the questions that follow.



21. If the variation in temperature over the years was influenced by a major volcanic eruption, when did the eruption most likely take place? Explain.

22. If the temperature were measured only once each year (at the beginning of the year), how would your interpretation be different?

Copyright © by Holt, Rinehart and Winston. All rights reserved.



Standardized Test Preparation

READING

Read each of the passages below. Then, answer the questions that follow each passage.

Passage 1 When the volcanic island of Krakatau in Indonesia exploded in 1883, a shock wave sped around the world seven times. The explosion was probably the loudest sound in recorded human history. What caused this enormous explosion? Most likely, the walls of the volcano ruptured, and ocean water flowed into the magma chamber of the volcano. The water instantly turned into steam, and the volcano exploded with the force of 100 million tons of TNT. The volcano ejected about 18 km^3 of volcanic material into the air. The ash clouds blocked out the sun, and everything within 80 km of the volcano was plunged into darkness for more than two days. The explosion caused a tsunami that was nearly 40 m high. Detected as far away as the English Channel, the tsunami destroyed almost 300 coastal towns. In 1928, another volcano rose from the caldera left by the explosion. This volcano is called Anak Krakatau.

1. In the passage, what does *tsunami* mean?

A a large earthquake
B a shock wave
C a giant ocean wave
D a cloud of gas and dust

2. According to the passage, what was the size of the Krakatau explosion probably the result of?

F pyroclastic material rapidly mixing with air
G 100 million tons of TNT
H an ancient caldera
I the flow of water into the magma chamber

3. What does the Indonesian word *anak* probably mean?

A father
B child
C mother
D grandmother

Passage 2 Yellowstone National Park in Montana and Wyoming contains three overlapping calderas and evidence of the cataclysmic ash flows that erupted from them. The oldest eruption occurred 1.9 million years ago, the second eruption happened 1.3 million years ago, and the most recent eruption occurred 0.6 million years ago. Seismographs regularly detect the movement of magma beneath the caldera, and the hot springs and geysers of the park indicate that a large body of magma lies beneath the park. The geology of the area shows that major eruptions occurred about once every 0.6 or 0.7 million years. Thus, a devastating eruption is long overdue. People living near the park should be evacuated immediately.

1. In the passage, what does *cataclysmic* mean?

A nonexplosive
B ancient
C destructive
D characterized by ash flows

2. Which of the following clues are evidence of an active magma body beneath the park?

F cataclysmic ash flows
G the discovery of seismoclasts
H minor eruptions
I seismograph readings

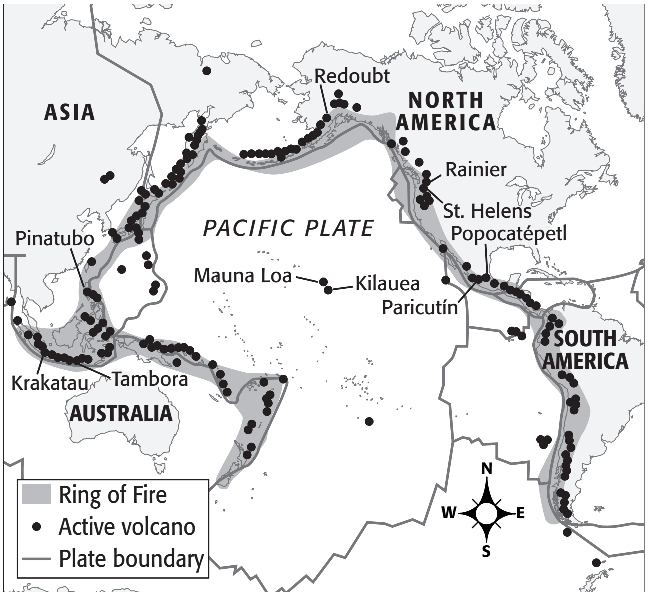
3. Which of the following contradicts the author's conclusion that an eruption is "long overdue"?

A Magma has been detected beneath the park.
B With a variation of 0.1 million years, an eruption may occur in the next 100,000 years.
C The composition of gases emitted indicates that an eruption is near.
D Seismographs have detected the movement of magma.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

INTERPRETING GRAPHICS

The map below shows some of the Earth's major volcanoes and the tectonic plate boundaries. Use the map below to answer the questions that follow.



1. If ash from Popocatépetl landed on the west coast of the United States, what direction did the ash travel?

A northeast
B northwest
C southeast
D southwest

2. Why aren't there any active volcanoes in Australia?

F Australia is not located on a plate boundary.
G Australia is close to Krakatau and Tambora.
H Australia is near a plate boundary.
I Australia is near a rift zone.

3. If a scientist traveled along the Ring of Fire from Mt. Redoubt to Krakatau, which of the following most accurately describes the directions in which she traveled?

A west, southeast, east
B west, southeast, west
C west, southwest, east
D west, southwest, west

MATH

Read each question below, and choose the best answer.

1. Midway Island is 1,935 km northwest of Hawaii. If the Pacific plate is moving to the northwest at a rate of 9 cm per year, how long ago was Midway Island over the hot spot that formed the island?

A 215,000 years
B 2,150,000 years
C 21,500,000 years
D 215,000,000 years

2. In the first year that the Mexican volcano Paricutín appeared in a cornfield, it grew 360 m. The volcano stopped growing at about 400 m. What percentage of the volcano's total growth occurred in the first year?

F 67%
G 82%
H 90%
I 92%

3. A pyroclastic flow is moving down a hill at 120 km/h. If you lived in a town 5 km away, how much time would you have before the flow reached your town?

A 2 min and 30 s
B 1 min and 21 s
C 3 min and 12 s
D 8 min and 3 s

4. The Columbia River plateau is a lava plateau that contains 350,000 km^3 of solidified lava. The plateau took 3 million years to form. What was the average rate of lava deposition each century?

F 0.116 km^3
G 11.6 km^3
H 116 km^3
I 11,600 km^3

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Science in Action

Weird Science

Pele's Hair

It is hard to believe that the fragile specimen shown below is a volcanic rock. This strange type of lava, called *Pele's hair,* forms when volcanic gases spray molten rock high into the air. When conditions are right, the lava can harden into strands of volcanic glass as thin as a human hair. This type of lava is named after Pele, the Hawaiian goddess of volcanoes. Several other types of lava are named in Pele's honor. Pele's tears are tear-shaped globs of volcanic glass often found at the end of strands of Pele's hair. Pele's diamonds are green, gemlike stones found in hardened lava flows.

Language Arts ACTIVITY

Volcanic terms come from many languages. Research some volcanic terms on the Internet, and create an illustrated volcanic glossary to share with your class.

Science, Technology, and Society

Fighting Lava with Fire Hoses

What would you do if a 60 ft wall of lava was advancing toward your home? Most people would head for safety. But when an eruption threatened to engulf the Icelandic fishing village of Heimaey in 1973, some villagers held their ground and fought back. Working 14-hour days in conditions so hot that their boots would catch on fire, villagers used fire-hoses to spray sea water on the lava flow. For several weeks, the lava advanced toward the town, and it seemed as if there was no hope. But the water eventually cooled the lava fast enough to divert the flow and save the village. It took 5 months and about 1.5 billion gallons of water to fight the lava flow. When the eruption stopped, villagers found that the island had grown by 20%!

Social Studies ACTIVITY

WRITING SKILL To try to protect the city of Hilo, Hawaii, from an eruption in 1935, planes dropped bombs on the lava. Find out if this mission was successful, and write a report about other attempts to stop lava flows.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Careers

Tina Neal

Volcanologist Would you like to study volcanoes for a living? Tina Neal is a volcanologist at the Alaska Volcano Observatory in Anchorage, Alaska. Her job is to monitor and study some of Alaska's 41 active volcanoes. Much of her work focuses on studying volcanoes in order to protect the public. According to Neal, being near a volcano when it is erupting is a wonderful adventure for the senses. "Sometimes you can get so close to an erupting volcano that you can feel the heat, hear the activity, and smell the lava. It's amazing! In Alaska, erupting volcanoes are too dangerous to get very close to, but they create a stunning visual display even from a distance."

Neal also enjoys the science of volcanoes. "It's fascinating to be near an active volcano and become aware of all the chemical and physical processes taking place. When I'm watching a volcano, I think about everything we understand and don't understand about what is happening. It's mind-boggling!" Neal says that if you are interested in becoming a volcanologist, it is important to be well rounded as a scientist. So, you would have to study math, geology, chemistry, and physics. Having a good understanding of computer tools is also important because volcanologists use computers to manage a lot of data and to create models. Neal also suggests learning a second language, such as Spanish. In her spare time, Neal is learning Russian so that she can better communicate with research partners in Kamchatka, Siberia.

Math ACTIVITY

The 1912 eruption of Mt. Katmai in Alaska could be heard 5,620 km away in Atlanta, Georgia. If the average speed of sound in the atmosphere is 342 m/s, how many hours after the eruption did the citizens of Atlanta hear the explosion?

go.hrw.com

To learn more about these Science in Action topics, visit **go.hrw.com** and type in the keyword **HZ5VOLF.**

Current Science

Check out Current Science® articles related to this chapter by visiting go.hrw.com. Just type in the keyword HZ5CS09.

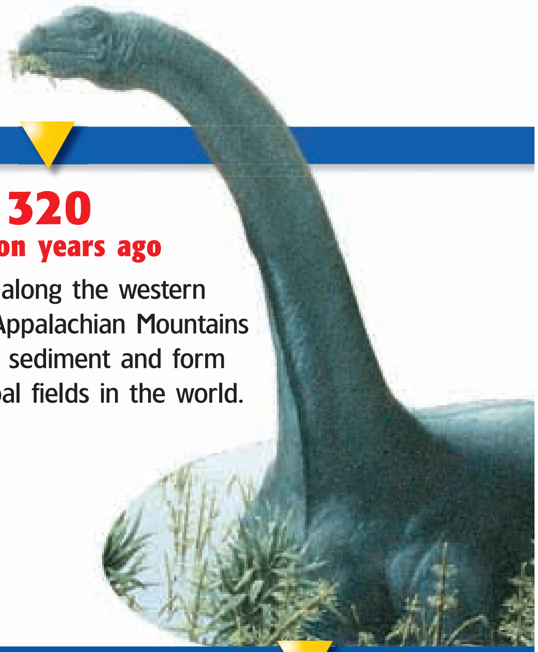
Copyright © by Holt, Rinehart and Winston. All rights reserved.

UNIT 2

TIMELINE

Reshaping the Earth

In this unit, you will learn about how the surface of the Earth is continuously reshaped. There is a constant struggle between the forces that build up the Earth's land features and the forces that break them down. This timeline shows some of the events that have occurred in this struggle as natural changes in the Earth's features took place.



320
Million years ago

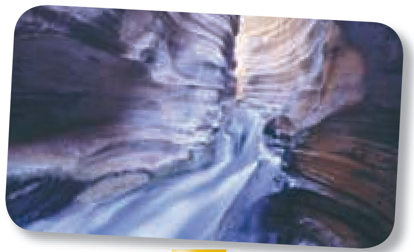
Vast swamps along the western edge of the Appalachian Mountains are buried by sediment and form the largest coal fields in the world.

6
Million years ago

The Colorado River begins to carve the Grand Canyon, which is roughly 2 km deep today.

10,000
years ago

The Great Lakes form at the end of the last Ice Age.



1930

Carlsbad Caverns National Park is established. It features the nation's deepest limestone cave and one of the largest underground chambers in the world.

Carlsbad Caverns

Copyright © by Holt, Rinehart and Winston. All rights reserved.

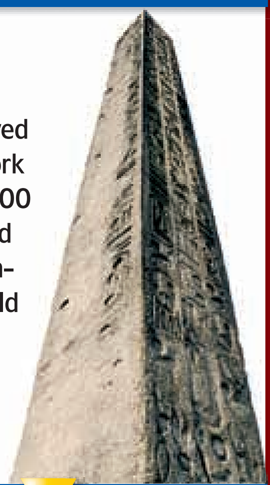
280
Million years ago
The shallow inland sea that covered much of what is now the upper midwestern United States fills with sediment and disappears.

140
Million years ago
The mouth of the Mississippi River is near present-day Cairo, Illinois.

65
Million years ago
Dinosaurs become extinct.

1775
The Battle of Bunker Hill, a victory for the Colonials, takes place on a drumlin, a tear-shaped mound of sediment that was formed by an ice-age glacier 10,000 years earlier.

1879
Cleopatra's Needle, a granite obelisk, is moved from Egypt to New York City. Within the next 100 years, the weather and pollution severely damage the 3,000-year-old monument.



1987
An iceberg twice the size of Rhode Island breaks off the edge of Antarctica's continental glacier.

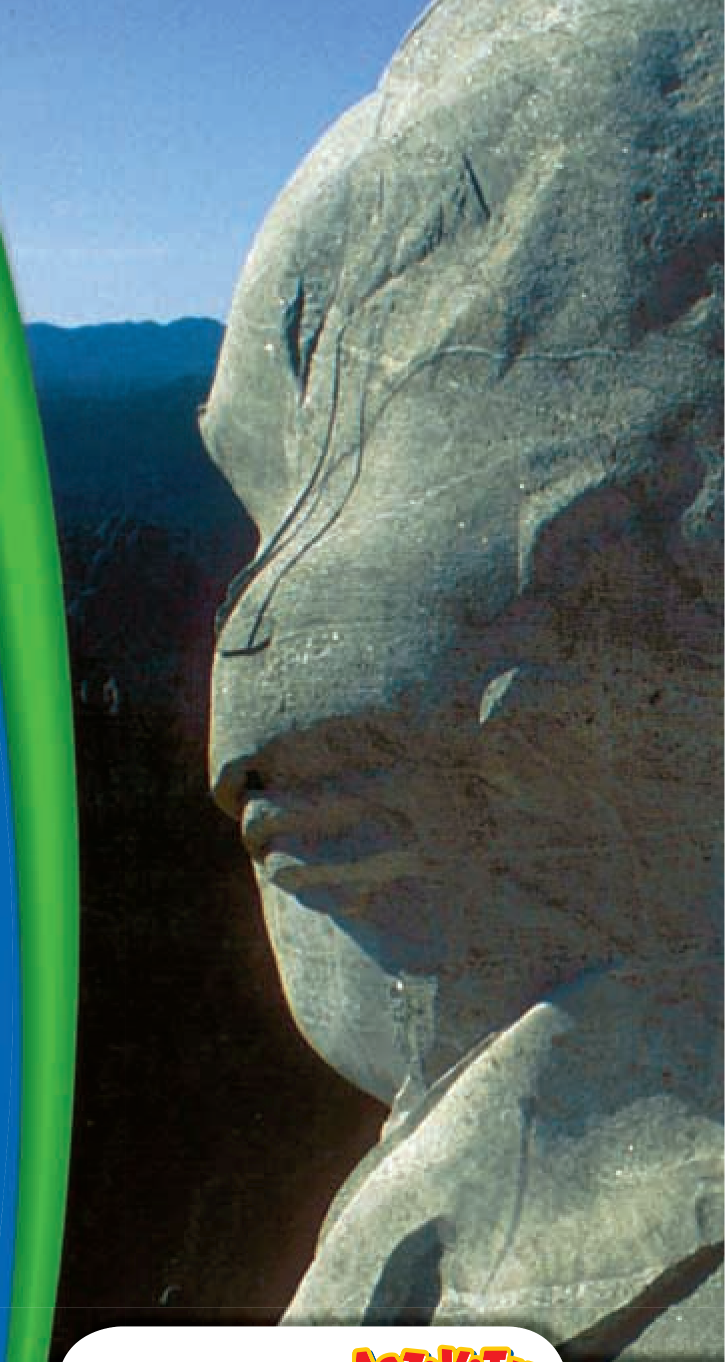
1998
Hong Kong opens a new airport on an artificially enlarged island. Almost 350 million cubic meters of rock and soil were deposited in the South China Sea to form the over 3,000-acre island.

2002
A NASA study finds that the arctic ice cap is melting at a rate of 9% per decade. At this rate, the ice cap could melt during this century.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

7

Weathering and Soil Formation



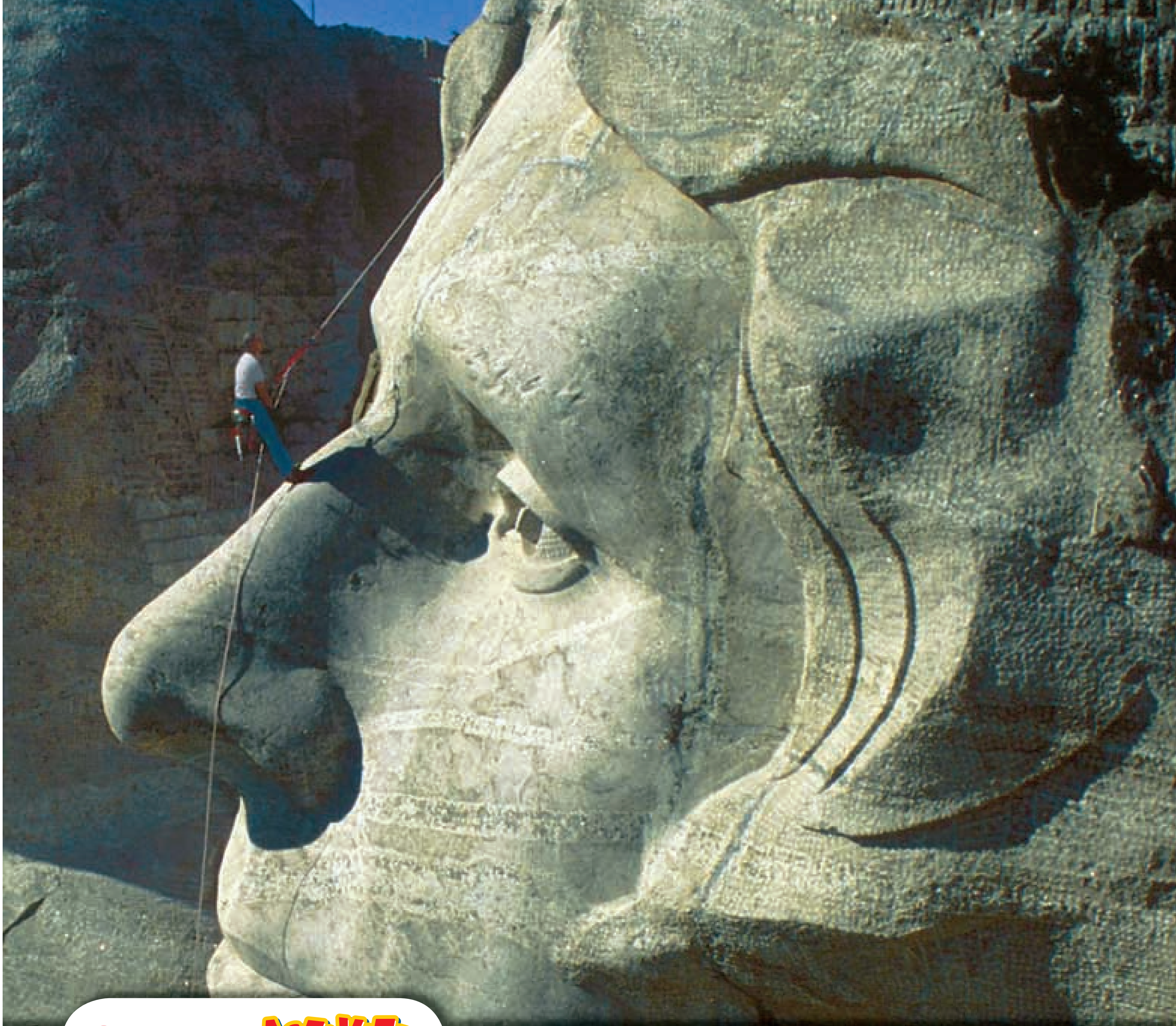
About the PHOTO

Need a nose job, Mr. President? The carving of Thomas Jefferson that is part of the Mount Rushmore National Memorial is having its nose inspected by a National Parks worker. The process of weathering has caused cracks to form in the carving of President Jefferson. National Parks workers use a sealant to protect the memorial from moisture, which can cause further cracking.

PRE-READING ACTIVITY

Key-Term Fold Before you read the chapter, create the FoldNote entitled "Key-Term Fold" described in the **Study Skills** section of the Appendix. Write a key term from the chapter on each tab of the key-term fold. Under each tab, write the definition of the key term.

Copyright © by Holt, Rinehart and Winston. All rights reserved.



START-UP ACTIVITY

What's the Difference?

In this chapter, you will learn about the processes and rates of weathering. Complete this activity to learn about how the size and surface area of a substance affects how quickly the substance breaks down.

Procedure

1. Fill **two small containers** about half full with **water.**
2. Add **one sugar cube** to one container.
3. Add **1 tsp of granulated sugar** to the other container.
4. Using **one spoon for each container,** stir the water and sugar in each container at the same rate.
5. Using a **stopwatch,** measure how long it takes for the sugar to dissolve in each container.

Analysis

1. Did the sugar dissolve at the same rate in both containers? Explain why or why not.
2. Do you think one large rock or several smaller rocks would wear away faster? Explain your answer.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 1

Weathering

If you have ever walked along a trail, you might have noticed small rocks lying around. Where did these rocks come from?

These smaller rocks came from larger rocks that were broken down. **Weathering** is the process by which rock materials are broken down by the action of physical or chemical processes.

Mechanical Weathering

If you were to crush one rock with another rock, you would be demonstrating one type of mechanical weathering. **Mechanical weathering** is the breakdown of rock into smaller pieces by physical means. Agents of mechanical weathering include ice, wind, water, gravity, plants, and even animals.

Ice

The alternate freezing and thawing of soil and rock, called *frost action,* is a form of mechanical weathering. One type of frost action, *ice wedging,* is shown in **Figure 1.** Ice wedging starts when water seeps into cracks during warm weather. When temperatures drop, the water freezes and expands. The ice then pushes against the sides of the crack. This causes the crack to widen.

READING WARM-UP

Objectives

- Describe how ice, water, wind, gravity, plants, and animals cause mechanical weathering.
- Describe how water, acids, and air cause chemical weathering of rocks.

Terms to Learn

weathering
mechanical weathering
abrasion
chemical weathering
acid precipitation

READING STRATEGY

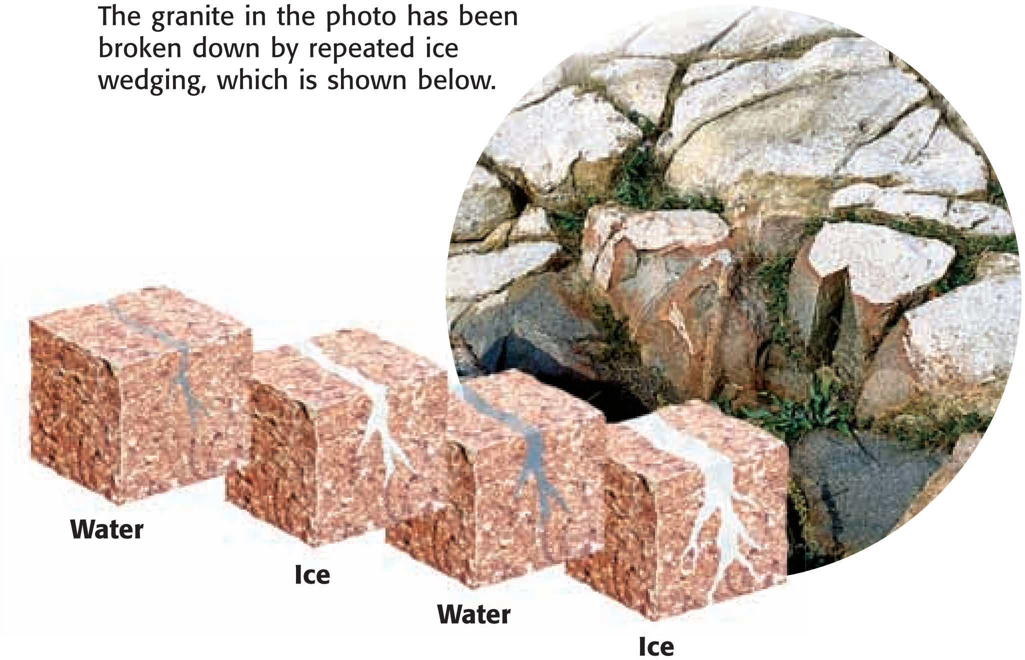
Paired Summarizing Read this section silently. In pairs, take turns summarizing the material. Stop to discuss ideas that seem confusing.

weathering the process by which rock materials are broken down by the action of physical and chemical processes

mechanical weathering the breakdown of rock into smaller pieces by physical means

Figure 1 Ice Wedging

The granite in the photo has been broken down by repeated ice wedging, which is shown below.

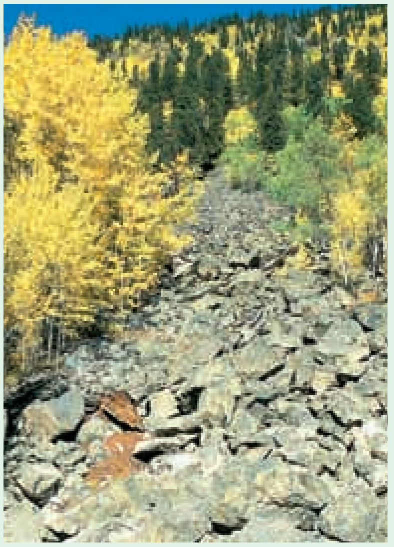


Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 2 **Three Forms of Abrasion**

These river rocks are rounded because they have been tumbled in the riverbed by fast-moving water for many years.

This rock has been shaped by blowing sand. Such rocks are called ventifacts.



Rocks grind against each other in a rock slide, which creates smaller and smaller rock fragments.

Abrasion

As you scrape a piece of chalk against a board, particles of the chalk rub off to make a line on the board and the piece of chalk wears down and becomes smaller. The same process, called *abrasion,* happens with rocks. **Abrasion** is the grinding and wearing away of rock surfaces through the mechanical action of other rock or sand particles.

abrasion the grinding and wearing away of rock surfaces through the mechanical action of other rock or sand particles

Wind, Water, and Gravity

Abrasion can happen in many ways, as shown in **Figure 2.** When rocks and pebbles roll along the bottom of swiftly flowing rivers, they bump into and scrape against each other. The weathering that occurs eventually causes these rocks to become rounded and smooth.

Wind also causes abrasion. When wind blows sand and silt against exposed rock, the sand eventually wears away the rock's surface. The figure above (center) shows what this kind of sandblasting can do to a rock.

Abrasion also occurs when rocks fall on one another. You can imagine the forces rocks exert on each other as they tumble down a mountainside. In fact, anytime one rock hits another, abrasion takes place.

Reading Check **Name three things that can cause abrasion.** (*See the Appendix for answers to Reading Checks.*)

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 3 *Although they grow slowly, tree roots are strong enough to break solid rock.*

Plants

You may not think of plants as being strong, but some plants can easily break rocks. Have you ever seen sidewalks and streets that are cracked because of tree roots? Roots don't grow fast, but they certainly are powerful! Plants often send their roots into existing cracks in rocks. As the plant grows, the force of the expanding root becomes so strong that the crack widens. Eventually, the entire rock can split apart, as shown in **Figure 3.**

Animals

Believe it or not, earthworms cause a lot of weathering! They burrow through the soil and move soil particles around. This exposes fresh surfaces to continued weathering. Would you believe that some kinds of tropical worms move an estimated 100 metric tons of soil per acre every year? Almost any animal that burrows causes mechanical weathering. Ants, worms, mice, coyotes, and rabbits are just some of the animals that contribute to weathering. **Figure 4** shows some of these animals in action. The mixing and digging that animals do often contribute to another type of weathering, called *chemical weathering*. You will learn about this type of weathering next.

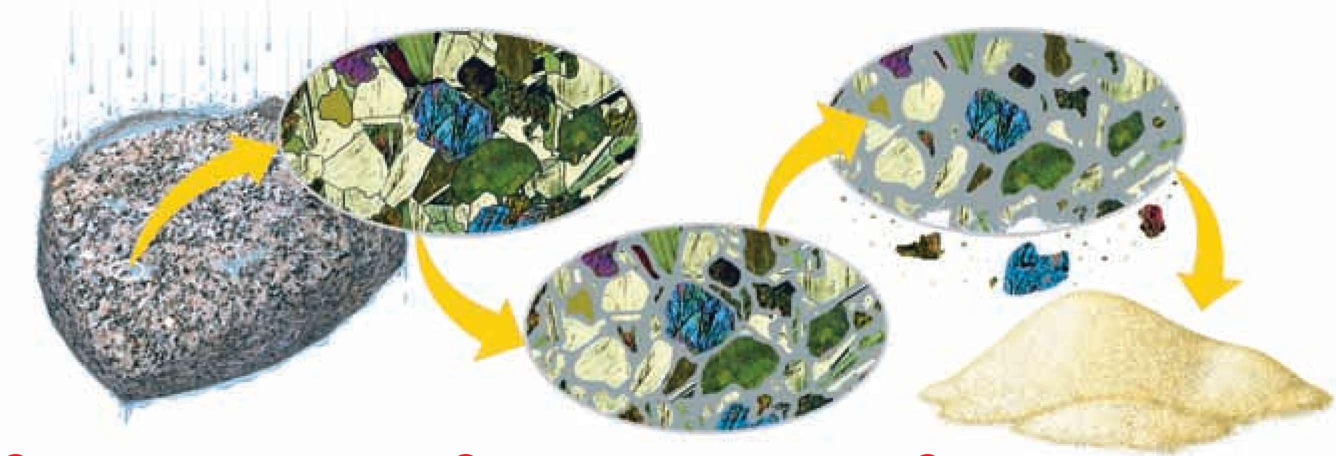
Reading Check **List three animals that can cause weathering.**

Figure 4 *Animals that live in the soil, such as moles, prairie dogs, insects, worms, and gophers, cause a lot of weathering. When the animals burrow in the ground, they break up soil and loosen rocks to be exposed to further weathering.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 5 Chemical Weathering of Granite

After thousands of years of chemical weathering, even hard rock, such as granite, can turn to sediment.



1 Rain, weak acids, and air chemically weather granite.

2 The bonds between mineral grains weaken as weathering proceeds.

3 When granite is weathered, it makes sand and clay, also called sediment.

Chemical Weathering

The process by which rocks break down as a result of chemical reactions is called **chemical weathering.** Common agents of chemical weathering are water, weak acids, and air.

chemical weathering the process by which rocks break down as a result of chemical reactions

acid precipitation rain, sleet, or snow, that contains a high concentration of acids

Water

If you drop a sugar cube into a glass of water, the sugar cube will dissolve after a few minutes. This process is an example of chemical weathering. Even hard rock, such as granite, can be broken down by water. But, it just may take thousands of years. **Figure 5** shows how granite is chemically weathered.

Acid Precipitation

Rain, sleet, or snow, that contains a high concentration of acids is called **acid precipitation.** Precipitation is naturally acidic. However, acid precipitation contains more acid than normal precipitation. The high level of acidity can cause very rapid weathering of rock. Small amounts of sulfuric and nitric acids from natural sources, such as volcanoes, can make precipitation acidic. However, acid precipitation can also be caused by air pollution from the burning of fossil fuels, such as coal and oil. When these fuels are burned, they give off gases, including sulfur oxides, nitrogen oxides, and carbon oxides. When these compounds combine with water in the atmosphere, they form weak acids, which then fall back to the ground in rain and snow. When the acidity is too high, acid precipitation can be harmful to plants and animals.

CONNECTION TO Chemistry

Acidity of Precipitation Acidity is measured by using a pH scale, the units of which range from 0 to 14. Solutions that have a pH of less than 7 are acidic. Research some recorded pH levels of acid rain. Then, compare these pH levels with the pH levels of other common acids, such as lemon juice and acetic acid.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 6 *Acid in groundwater has weathered limestone to form Carlsbad Caverns, in New Mexico.*

Acids in Groundwater

In certain places groundwater contains weak acids, such as carbonic or sulfuric acid. These acids react with rocks in the ground, such as limestone. When groundwater comes in contact with limestone, a chemical reaction occurs. Over a long period of time, the dissolving of limestone forms *karst* features, such as caverns. The caverns, like the one shown in **Figure 6,** form from the eating away of the limestone.

Acids in Living Things

Another source of acids that cause weathering might surprise you. Take a look at the lichens in **Figure 7.** Lichens produce acids that can slowly break down rock. If you have ever taken a walk in a park or forest, you have probably seen lichens growing on the sides of trees or rocks. Lichens can also grow in places where some of the hardiest plants cannot. For example, lichens can grow in deserts, in arctic areas, and in areas high above timberline, where even trees don't grow.

Figure 7 *Lichens, which consist of fungi and algae living together, contribute to chemical weathering.*

QuickLab

Acids React!

1. Ketchup is one example of a food that contains weak acids, which react with certain substances. Take a **penny** that has a dull appearance, rub **ketchup** on it for several minutes.
2. Rinse the penny.
3. Where did all the grime on the penny go?
4. How is this process similar to what happens to a rock when it is exposed to natural acids during weathering?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Air

The car shown in **Figure 8** is undergoing chemical weathering due to the air. The oxygen in the air is reacting with the iron in the car, causing the car to rust. Water speeds up the process. But the iron would rust even if no water were present. Scientists call this process oxidation.

Oxidation is a chemical reaction in which an element, such as iron, combines with oxygen to form an oxide. This common form of chemical weathering is what causes rust. Old cars, aluminum cans, and your bike can experience oxidation if left exposed to air and rain for long periods of time.

Reading Check What can cause oxidation?

Figure 8 *Rust is a result of chemical weathering.*

SECTION Review

Summary

- Ice wedging is a form of mechanical weathering in which water seeps into rock cracks and then freezes and expands.
- Wind, water, and gravity cause mechanical weathering by abrasion.
- Animals and plants cause mechanical weathering by turning the soil and breaking apart rocks.
- Water, acids, and air chemically weather rock by weakening the bonds between mineral grains of the rock.

Using Key Terms

1. In your own words, write a definition for each of the following terms: *weathering, mechanical weathering, abrasion, chemical weathering* and *acid precipitation*.

Understanding Key Ideas

2. Which of the following things cannot cause mechanical weathering?
   a. water
   b. acid
   c. wind
   d. animals
3. List three things that cause chemical weathering of rocks.
4. Describe three ways abrasion occurs in nature.
5. Describe the similarity in the ways tree roots and ice mechanically weather rock.
6. Describe five sources of chemical weathering.

Critical Thinking

7. **Making Inferences** Why does acid precipitation weather rocks faster than normal precipitation?
8. **Making Comparisons** Compare the weather processes that affect a rock on top of a mountain and a rock buried beneath the ground.

Math Skills

9. Substances that have a pH of less than 7 are acidic. For each pH unit lower, the acidity is ten times greater. For example, normal precipitation is slightly acidic at a 5.6 pH. If acid precipitation were measured at 4.6 pH, it would be 10 times more acidic than normal precipitation. How many times more acidic would precipitation at 3.6 pH be than normal precipitation?

SCILINKS® NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Weathering
SciLinks code: HSM1648

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 2

Rates of Weathering

Have you ever seen a cartoon in which a character falls off a cliff and lands on a ledge? Ledges exist in nature because the rock that the ledge is made of weathers more slowly than the surrounding rock.

READING WARM-UP

Objectives

- Explain how the composition of rock affects the rate of weathering.
- Describe how a rock's total surface area affects the rate at which the rock weathers.
- Describe how differences in elevation and climate affect the rate of weathering.

Terms to Learn

differential weathering

READING STRATEGY

Reading Organizer As you read this section, create an outline of the section. Use the headings from the section in your outline.

Weathering is a process that takes a long time. However, some rock will weather faster than other rock. The rate at which a rock weathers depends on climate, elevation, and the makeup of the rock.

Differential Weathering

Hard rocks, such as granite, weather more slowly than softer rocks, such as limestone. **Differential weathering** is a process by which softer, less weather resistant rocks wear away and leave harder, more weather resistant rocks behind.

Figure 1 shows a landform that has been shaped by differential weathering. Devils Tower was once a mass of molten rock deep inside an active volcano. When the molten rock cooled and hardened, it was protected from weathering by the outer rock of the volcano. After thousands of years of weathering, the soft outer parts of the volcano have worn away. The harder, more resistant rock is all that remains.

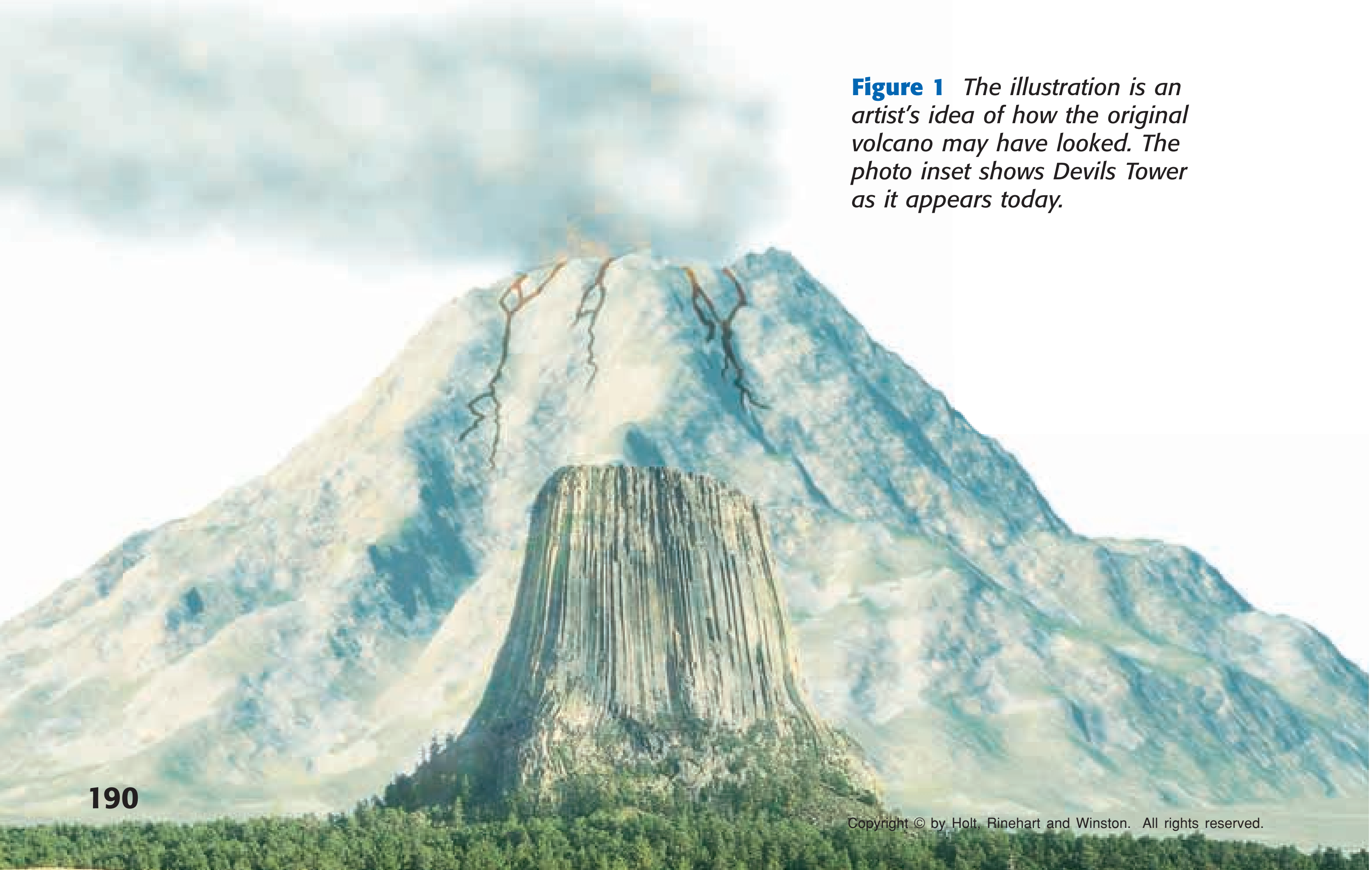


Figure 1 *The illustration is an artist's idea of how the original volcano may have looked. The photo inset shows Devils Tower as it appears today.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

The Shape of Rocks

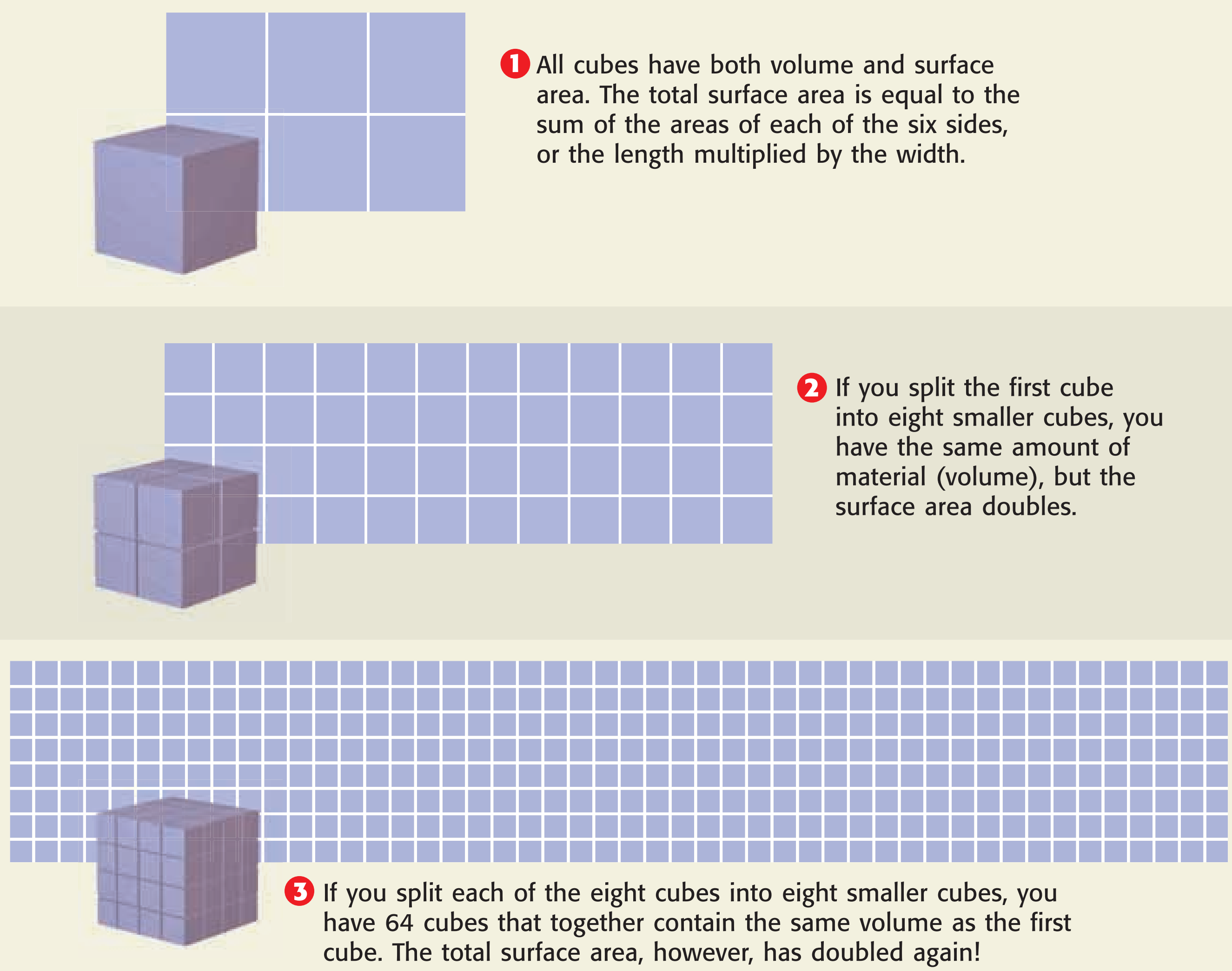
Weathering takes place on the outer surface of rocks. Therefore, the more surface area that is exposed to weathering, the faster the rock will be worn down. A large rock has a large surface area. But a large rock also has a large volume. Because of the large rock's volume, the large rock will take a long time to wear down.

If a large rock is broken into smaller fragments, weathering of the rock happens much more quickly. The rate of weathering increases because a smaller rock has more surface area to volume than a larger rock has. So, more of a smaller rock is exposed to the weathering process. **Figure 2** shows this concept in detail.

differential weathering the process by which softer, less weather resistant rocks wear away and leave harder, more weather resistant rocks behind

Reading Check **How does an increase in surface area affect the rate of weathering?** (*See the Appendix for answers to Reading Checks.*)

Figure 2 Total Surface Area to Volume



1. All cubes have both volume and surface area. The total surface area is equal to the sum of the areas of each of the six sides, or the length multiplied by the width.

2. If you split the first cube into eight smaller cubes, you have the same amount of material (volume), but the surface area doubles.

3. If you split each of the eight cubes into eight smaller cubes, you have 64 cubes that together contain the same volume as the first cube. The total surface area, however, has doubled again!

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Weathering and Climate

The rate of weathering in an area is greatly affected by the climate of that area. *Climate* is the average weather condition in an area over a long period of time. For example, the two mailboxes shown in **Figure 3** are in two different climates. The mailbox on the left is in a dry climate. The mailbox on the right is in a warm, humid climate. As you can see, the mailbox in the warm, humid climate is rusty.

Temperature and Water

The rate of chemical weathering happens faster in warm, humid climates. The rusty mailbox has experienced a type of chemical weathering called oxidation. Oxidation, like other chemical reactions, happens at a faster rate when temperatures are higher and when water is present.

Water also increases the rate of mechanical weathering. The freezing of water that seeps into the cracks of rocks is the process of ice wedging. Ice wedging causes rocks to break apart. Over time, this form of weathering can break down even the hardest rocks into soil.

Temperature is another major factor in mechanical weathering. The more often temperatures cause freezing and thawing, the more often ice wedging takes place. Therefore, climatic regions that experience frequent freezes and thaws have a greater rate of mechanical weathering.

Reading Check **Why would a mailbox in a warm, humid climate experience a higher rate of weathering than a mailbox in a cold, dry climate?**

School to Home

Ice Wedging

WRITING SKILL To understand ice wedging, try this activity at home with a parent. Fill a small, plastic water bottle with water. Plug the opening with a piece of putty. Place the bottle in the freezer overnight. Describe in your **science journal** what happened to the putty.

Activity

Figure 3 *These photos show the effects different climates can have on rates of weathering.*

This mailbox is in a dry climate and does not experience a high rate of weathering.

This mailbox is in a warm, humid climate. It experiences a high rate of chemical weathering called oxidation.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Weathering and Elevation

Just like everything else, mountains are exposed to air and water. As a result, mountain ranges are weathered down. Weathering happens on mountains in the same way it does everywhere else. However, as shown in **Figure 4,** rocks at higher elevations, as on a mountain, are exposed to more wind, rain, and ice than the rocks at lower elevations are. This increase in wind, rain, and ice at higher elevations causes the peaks of mountains to weather faster.

Gravity affects weathering, too. The steepness of mountain slopes increases the effects of mechanical and chemical weathering. Steep slopes cause rainwater to quickly run off the sides of mountains. The rainwater carries the sediment down the mountain's slope. This continual removal of sediment exposes fresh rock surfaces to the effects of weathering. New rock surfaces are also exposed to weathering when gravity causes rocks to fall away from the sides of mountains. The increased surface area means weathering happens at a faster rate.

Reading Check **Why do mountaintops weather faster than rocks at sea level?**

Figure 4 *The ice, rain, and wind that these mountain peaks are exposed to cause them to weather at a fast rate.*

SECTION Review

Summary

- Hard rocks weather more slowly than softer rocks.
- The more surface area of a rock that is exposed to weathering, the faster the rock will be worn down.
- Chemical weathering occurs faster in warm, humid climates.
- Weathering occurs faster at high elevations because of an increase in ice, rain, and wind.

Using Key Terms

1. In your own words, write a definition for the term *differential weathering*.

Understanding Key Ideas

2. A rock will have a lower rate of weathering when the rock
   a. is in a humid climate.
   b. is a very hard rock, such as granite.
   c. is at a high elevation.
   d. has more surface area exposed to weathering.
3. How does surface area affect the rate of weathering?
4. How does climate affect the rate of weathering?
5. Why does the peak of a mountain weather faster than the rocks at the bottom of the mountain?

Math Skills

6. The surface area of an entire cube is 96 cm^2. If the length and width of each side are equal, what is the length of one side of the cube?

Critical Thinking

7. **Making Inferences** Does the rate of chemical weathering increase or stay the same when a rock becomes more mechanically weathered? Why?

SCILINKS® NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Rates of Weathering
SciLinks code: HSM1269

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 3

From Bedrock to Soil

Most plants need soil to grow. But what exactly is soil? Where does it come from?

READING WARM-UP

Objectives

- Describe the source of soil.
- Explain how the different properties of soil affect plant growth.
- Describe how various climates affect soil.

Terms to Learn

soil	soil structure
parent rock	humus
bedrock	leaching
soil texture	

READING STRATEGY

Prediction Guide Before you read this section, write the title of each heading in this section. Next, under each heading, write what you think you will learn.

The Source of Soil

To a scientist, **soil** is a loose mixture of small mineral fragments, organic material, water, and air that can support the growth of vegetation. But not all soils are the same. Because soils are made from weathered rock fragments, the type of soil that forms depends on the type of rock that weathers. The rock formation that is the source of mineral fragments in the soil is called **parent rock.**

Bedrock is the layer of rock beneath soil. In this case, the bedrock is the parent rock because the soil above it formed from the bedrock below. Soil that remains above its parent rock is called *residual soil.*

Soil can be blown or washed away from its parent rock. This soil is called *transported soil.* **Figure 1** shows one way that soil is moved from one place to another. Both wind and the movement of glaciers are also responsible for transporting soil.

Reading Check **What is soil formed from?** (*See the Appendix for answers to Reading Checks.*)

soil a loose mixture of rock fragments, organic material, water, and air that can support the growth of vegetation

parent rock a rock formation that is the source of soil

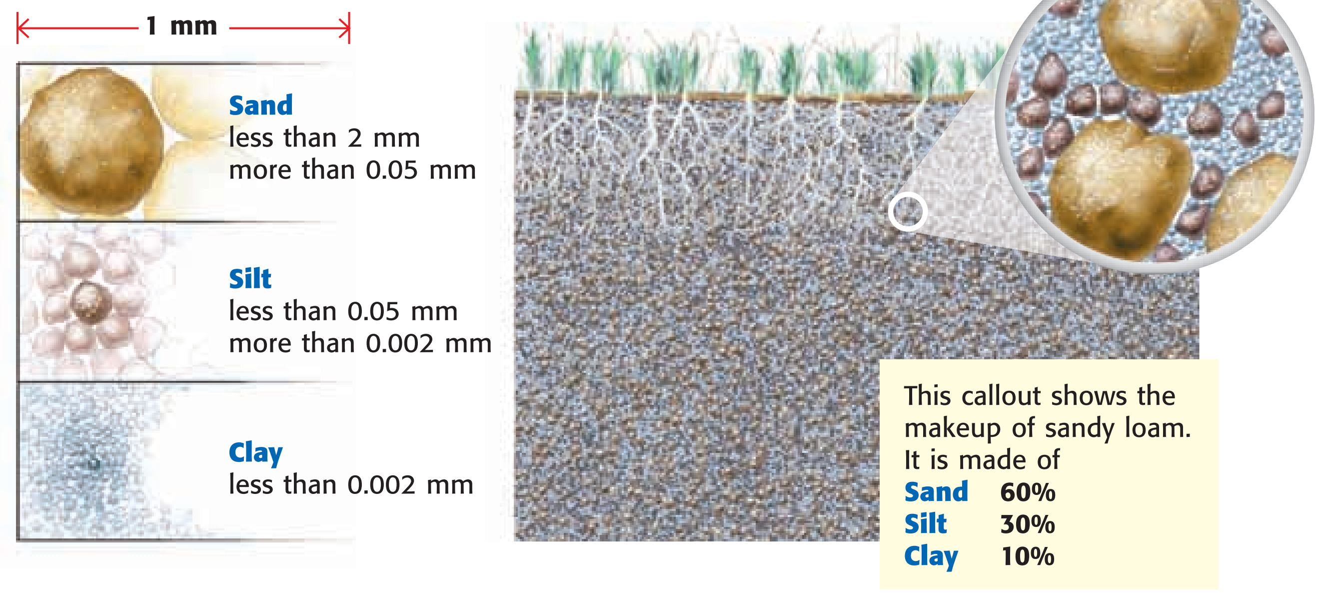
bedrock the layer of rock beneath soil

Figure 1 *Transported soil may be moved long distances from its parent rock by rivers, such as this one.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 2 **Soil Texture**

The proportion of these different-sized particles in soil determine the soil's texture.



Soil Properties

Some soils are great for growing plants. Other soils can't support the growth of plants. To better understand soil, you will next learn about its properties, such as soil texture, soil structure, and soil fertility.

Soil Texture and Soil Structure

Soil is made of different-sized particles. These particles can be as large as 2 mm, such as sand. Other particles can be too small to see without a microscope. **Soil texture** is the soil quality that is based on the proportions of soil particles. **Figure 2** shows the soil texture for one type of soil.

Soil texture affects the soil's consistency. Consistency describes a soil's ability to be worked and broken up for farming. For example, soil texture that has a large proportion of clay can be hard and difficult for farmers to break up.

Soil texture influences the *infiltration,* or ability of water to move through soil. Soil should allow water to get to the plants' roots without causing the soil to be completely saturated.

Water and air movement through soil is also influenced by soil structure. **Soil structure** is the arrangement of soil particles. Soil particles are not always evenly spread out. Often, one type of soil particle will clump in an area. A clump of one type of soil can either block water flow or help water flow, which affects soil moisture.

soil texture the soil quality that is based on the proportions of soil particles.

soil structure the arrangement of soil particles

Copyright © by Holt, Rinehart and Winston. All rights reserved.

humus the dark, organic material formed in soil from the decayed remains of plants and animals

leaching the removal of substances that can be dissolved from rock, ore, or layers of soil due to the passing of water

Soil Fertility

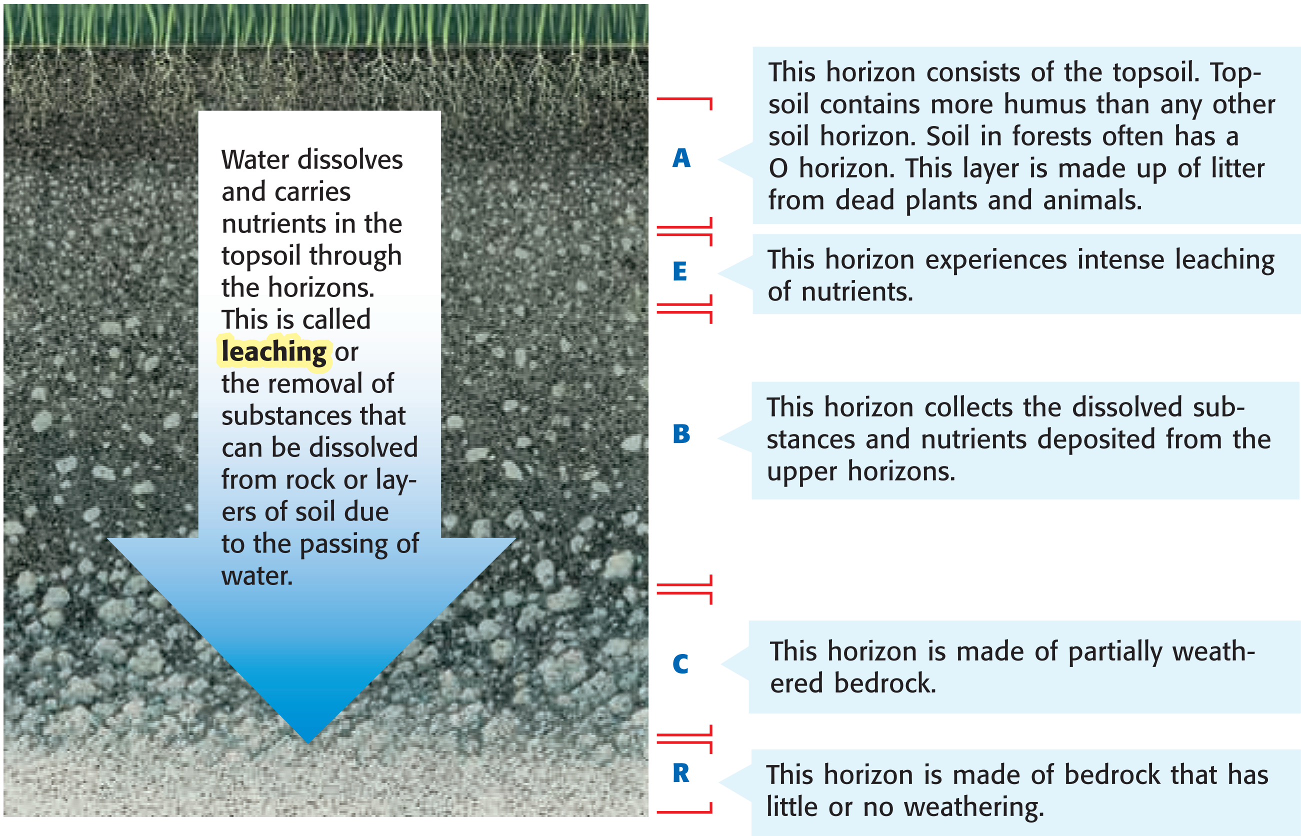
Nutrients in soil, such as iron, are necessary for plants to grow. Some soils are rich in nutrients. Other soils may not have many nutrients or are not able to supply the nutrients to the plants. A soil's ability to hold nutrients and to supply nutrients to a plant is described as *soil fertility*. Many nutrients in soil come from the parent rock. Other nutrients come from **humus,** which is the organic material formed in soil from the decayed remains of plants and animals. These remains are broken down into nutrients by decomposers, such as bacteria and fungi.

Soil Horizons

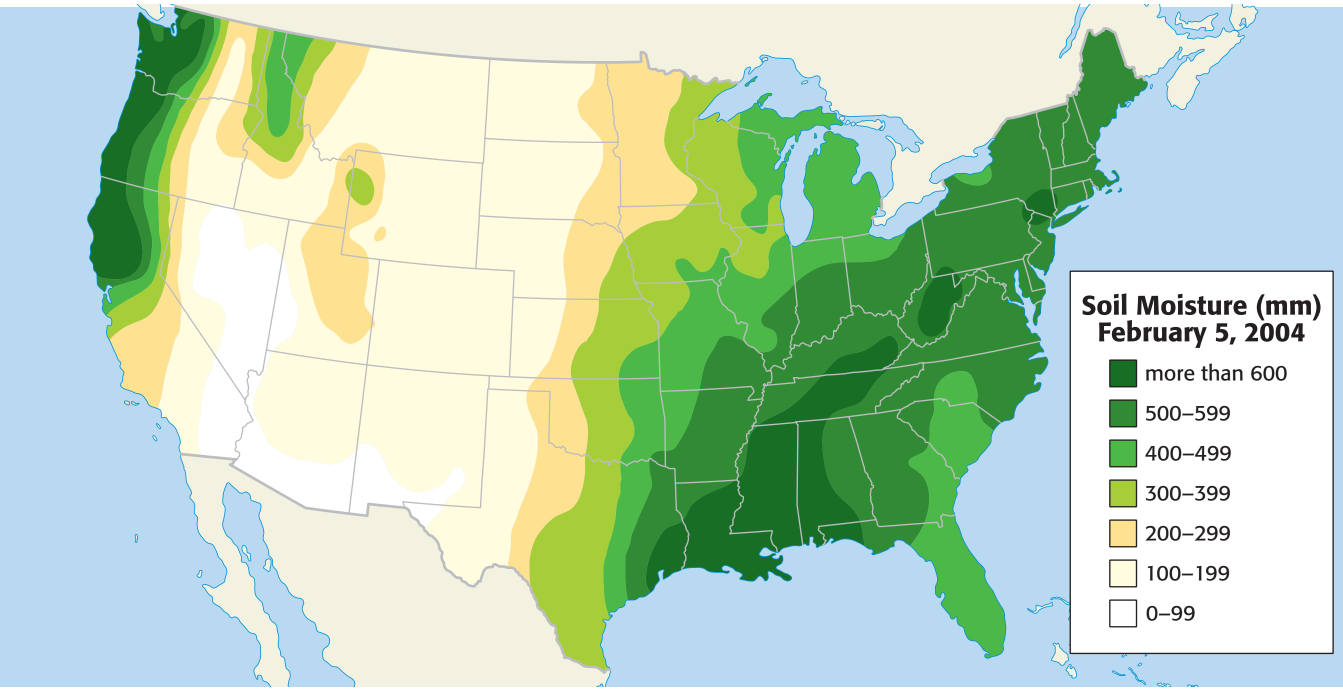
Because of the way soil forms, soil often ends up in a series of layers, with humus-rich soil on top, sediment below that, and bedrock on the bottom. Geologists call these layers *horizons*. The word *horizon* tells you that the layers are horizontal. **Figure 3** shows what these horizons can look like. You can see these layers in some road cuts.

The top layer of soil is often called the *topsoil*. Topsoil contains more humus than the layers below it. The humus is rich in the nutrients plants need to be healthy. This is why good topsoil is necessary for farming.

Figure 3 **Soil Horizons**



Copyright © by Holt, Rinehart and Winston. All rights reserved.



Source: NOAA Climate Prediction Center

Figure 4 *The map above models the depth of soil moisture in the continental United States on February 5, 2004. Soil moisture values in North Carolina were between 400 and 599 mm.*

Soil Temperature and Moisture

Soil temperature is important to plant growth. Plant growth is slowed if soil temperature is too high or too low. So, soil temperature must be monitored by growers to make sure that it is optimum for plant growth.

The water that is held in the spaces between soil particles is called *soil moisture*. Soil moisture is important because the amount of moisture in the soil determines whether precipitation will infiltrate or run off the soil. A map that models soil moisture in the United States is shown in **Figure 4.**

Soil pH

Soil pH influences which nutrients will be available to plants from the soil. Certain nutrients will not be available to plants in soils that are basic, or have a high pH. Other nutrients will not be available to plants in soils that are acidic, or have low pH. Because nutrient needs vary between plant types, the best soil pH for growing varies between plant types, too.

Soil Color

Soil color can be related to soil fertility. Soils that are black or dark brown usually contain organic matter and are fertile. Reddish or yellowish soils often contain oxidized iron. These are fertile, too. However, soils that are whitish may contain salts. Salts may make soils unsuitable for farming.

Reading Check **Which soil colors indicate fertile soils?**

CONNECTION TO Meteorology

Soil Moisture and Weather Forecasting Did you realize that soil moisture plays an important role in weather forecasting? The amount of moisture that soil contains can be directly linked to air temperature. For example, high soil moisture can increase the dewpoint and keep nighttime low temperatures from dropping significantly. Soil moisture can also be used to forecast precipitation. High soil moisture, which supplies moisture to the atmosphere through evaporation, can increase the chance of precipitation.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 5 *Lush tropical rain forests have surprisingly thin topsoil.*

Soil and Climate

Soil types vary from place to place. One reason for this is the differences in climate. As you read on, you will see that climate can make a difference in the types of soils that develop around the world.

Tropical Rain Forest Climates

Take a look at **Figure 5.** In tropical rain forest climates, the air is very humid and the land receives a large amount of rain. Because of warm temperatures, crops can be grown year-round. The warm soil temperature also allows dead plants and animals to decay rapidly. This provides rich humus to the soil.

Because of the lush plant growth, you may think that tropical rain forest soils are the most nutrient-rich in the world. However, tropical rain forest soils are nutrient poor. The heavy rains in this climate leach precious nutrients from the topsoil into deeper layers of soil. The result is that tropical topsoil is very thin. Another reason tropical rain forest soil is nutrient poor is that the lush vegetation has a great demand for nutrients. The nutrients that aren't leached away are quickly taken up by plants and trees that live off the soil.

Reading Check **Why is the topsoil in tropical rain forests thin?**

Deforestation

Clearing trees from an area without replacing them is called *deforestation*. As populations expand and the demand for lumber products and wood for fuel increases, parts of the world are becoming deforested. Nowhere is the rate of deforestation as rapid as in tropical rain forests, where land is being converted to agriculture and for cattle grazing. Because the soil of tropical rain forests is thin, nutrients can be depleted quickly. Farmers must move from one plot of land to another to find fertile soil to farm. Each plot must be cleared of forest to make it suitable for agriculture. If land for farming is not quickly planted with cover crops, the thin soil will wash away. Similarly, if land is cleared by logging or by the collection of wood for fuel and trees are not rapidly replanted, the soil will wash away.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Desert Climates

While tropical climates get a lot of rain, deserts get less than 25 cm a year. Leaching of nutrients is not a problem in desert soils. But the lack of rain causes many other problems, such as very low rates of chemical weathering and less ability to support plant and animal life. A low rate of weathering means soil is created at a slower rate.

Some water is available from groundwater. Groundwater can trickle in from surrounding areas and seep to the surface. But as soon as the water is close to the surface, it evaporates. So, any materials that were dissolved in the water are left behind in the soil. Without the water to dissolve the minerals, the plants are unable to take them up. Often, the chemicals left behind are various types of salts. These salts can sometimes become so concentrated that the soil becomes toxic, or poisonous, even to desert plants! Death Valley, shown in **Figure 6,** is a desert that has toxic levels of salt in the soil.

INTERNET ACTIVITY

For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HZ5WSFW.**

Land Degradation

Land degradation occurs when either natural processes or human activity damage land to the point that it can no longer support plants and animals. In areas that have dry climates, a process called *desertification* can take place. Through this process, land becomes more desertlike as a result of a change in climate or human activity. Desertification may be caused by drought, a long period during which rainfall is below average. Human activities that can cause desertification include farming methods that cause soil to lose its fertility and productivity, livestock overgrazing, and deforestation.

Figure 6 *The dry conditions and salt content of desert soils make it difficult for many plants to survive.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 7 *The rich soils in areas that have a temperate climate support a vast farming industry.*

Temperate Forest and Grassland Climates

Much of the continental United States has a temperate climate. An abundance of weathering occurs in temperate climates. Temperate areas get enough rain to cause a high level of chemical weathering, but not so much that the nutrients are leached out of the soil. Frequent changes in temperature lead to frost action. As a result, thick, fertile soils develop, as shown in **Figure 7.**

Temperate soils are some of the most productive soils in the world. In fact, the midwestern part of the United States has earned the nickname “breadbasket” for the many crops the region’s soil supports.

Reading Check **Which climate has the most productive soil?**

Arctic Climates

Arctic areas have so little precipitation that they are like cold deserts. In arctic climates, as in desert climates, chemical weathering occurs very slowly. So, soil formation also occurs slowly. Slow soil formation is why soil in arctic areas, as shown in **Figure 8,** is thin and unable to support many plants.

Arctic climates also have low soil temperatures. At low temperatures, decomposition of plants and animals happens more slowly or stops completely. Slow decomposition limits the amount of humus in the soil, which limits the nutrients available. These nutrients are necessary for plant growth.

Figure 8 *Arctic soils, such as the soil along Denali Highway, in Alaska, cannot support lush vegetation.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION Review

Summary

- Soil is formed from the weathering of bedrock.
- Soil texture affects how soil can be worked for farming and how well water passes through it.
- The ability of soil to provide nutrients so that plants can survive and grow is called *soil fertility*.
- For plants to grow well, soil temperature must be optimum.
- The amount of moisture in the soil determines whether precipitation will infiltrate or run off the soil.
- The pH of a soil influences which nutrients plants can take up from the soil.
- Soil color is related to soil fertility.
- Different climates have different types of soil, depending on the temperature and rainfall.
- Deforestation and desertification cause soil to lose its fertility and productivity and to be washed away.
- Temperate soils are some of the most productive soils in the world.

Using Key Terms

1. Use each of the following terms in a separate sentence: *soil, parent rock, bedrock, soil texture, soil structure, humus,* and *leaching.*

Understanding Key Ideas

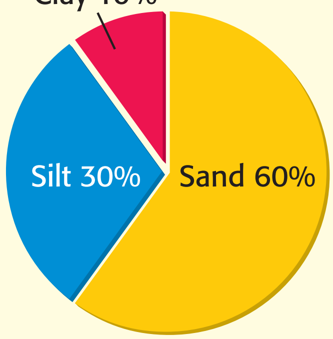
2. Which of the following soil properties influences soil moisture?
   a. soil horizon
   b. soil fertility
   c. soil structure
   d. soil pH
3. When is parent rock the same as bedrock?
4. What is the difference between residual and transported soils?
5. Which climate has the most thick, fertile soil?
6. How does soil temperature influence arctic soil?

Critical Thinking

7. **Identifying Relationships** In which type of climate would leaching be more common—tropical rain forest or desert?
8. **Making Comparisons** Explain why arctic soils and desert soils are similar even though arctic climates and desert climates are different.

Interpreting Graphics

Use the graph below to answer the question that follows.



9. Which of the following soil types does this graph most likely represent?
   a. clay loam
   b. silty loam
   c. sandy loam
   d. silty clay

SCILINKS® NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Soil and Climate
SciLinks code: HSM1408

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 4

Soil Conservation

Believe it or not, soil can be endangered, just like plants and animals. Because soil takes thousands of years to form, it is not easy to replace. Practicing good stewardship of the soil helps maintain fertile soil for future generations.

READING WARM-UP

Objectives

- Describe three important benefits that soil provides.
- Describe four methods of preventing soil damage and loss.

Terms to Learn

soil conservation
erosion
salinization

READING STRATEGY

Reading Organizer As you read this section, make a table comparing the four methods of preventing soil damage and loss.

If we do not take care of our soils, we can ruin them or even lose them. Soil is a resource that must be conserved. **Soil conservation** is a method to maintain the fertility of the soil by protecting the soil from erosion and nutrient loss.

soil conservation a method to maintain the fertility of the soil by protecting the soil from erosion and nutrient loss

The Importance of Soil

Soil provides minerals and other nutrients for plants. If the soil loses these nutrients, then plants will not be able to grow. Take a look at the plants shown in **Figure 1.** The plants on the right look unhealthy because they are not getting enough nutrients. There is enough soil to support the plant's roots, but the soil is not providing them with the food they need. The plants on the left are healthy because the soil they live in is rich in nutrients.

All animals get their energy from plants. The animals get their energy either by eating the plants or by eating animals that have eaten plants. So, if plants can't get their nutrients from the soil, animals can't get their nutrients from plants.

Reading Check **Why is soil important?** (*See the Appendix for answers to Reading Checks.*)

Figure 1 *Both of these photos show the same crop, but the soil in the photo on the right is poor in nutrients.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

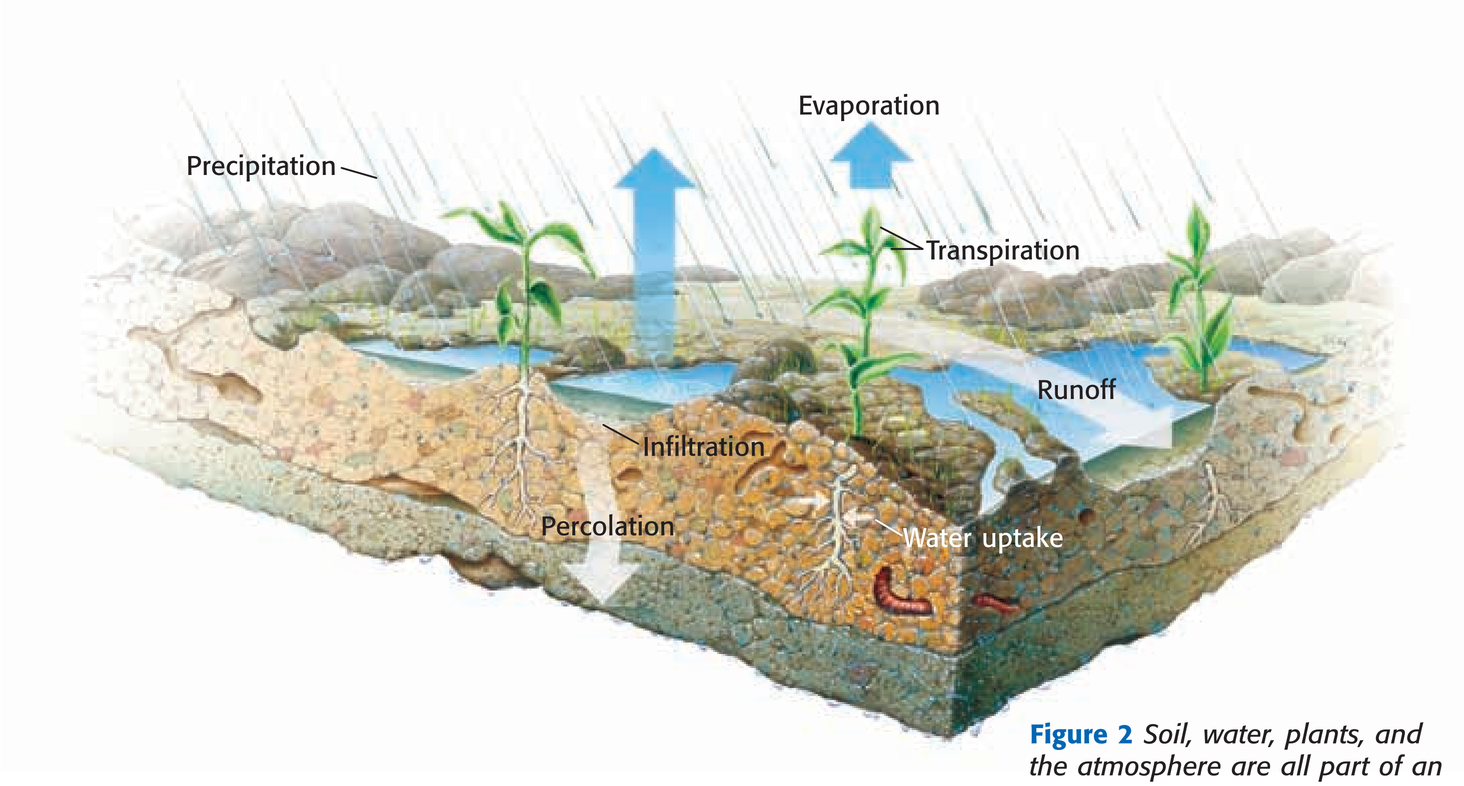


Figure 2 *Soil, water, plants, and the atmosphere are all part of an interrelated natural cycle.*

Soil and Water

Soil, water, plants, and the atmosphere are all part of a natural cycle that is shown in **Figure 2.** When it rains, the force of gravity causes water that collects on the ground to infiltrate the soil and move downward, or percolate, through the spaces between soil particles. Some of this water seeps down to the water table. The water that remains between soil particles acts as water storage for plants. The water also contains the nutrients that plants need to survive. Plants take in this water through their roots and release it through their leaves in a process called *transpiration*. The water vapor that is released by plants becomes low-level moisture in the atmosphere.

Soil and Organisms

Did you know that 1 g of fertile soil can contain as many as 1 billion bacterial cells? These bacterial cells are the most numerous organisms of the soil ecosystem. Other organisms that live in the soil include plants, fungi, worms, insects, and small mammals. Each of these organisms plays an important role in the soil ecosystem. For example, certain bacteria can convert nitrogen into chemical compounds that plants use. And the burrowing activity of earthworms not only mixes and binds soil but also creates channels in the soil through which plant roots grow. If the soil disappears, the habitat for these organisms does, too.

CONNECTION TO Environmental Science

WRITING SKILL **North Carolina State Soil** Did you know that North Carolina has a state soil? The soil is called *Cecil,* and it is found on approximately 650,000 hectares in North Carolina. Cecil is usually composed of a brown to dark-gray sandy loam topsoil and red-clay subsoil. Cecil is a deep soil that has a depth to bedrock of between 2 and 6 m or more and is formed from weathered igneous and metamorphic rock. Find out more information about Cecil, and summarize your findings in a short essay.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 3 *Providence Canyon, located near Columbus, Georgia, began forming in the early 1800s. Erosion of the soft sand in the canyon continues today.*

Soil Damage and Loss

What would happen if there were no soil? Soil loss is a serious problem around the world. Soil damage can lead to soil loss. Soil can be damaged from overuse by poor farming techniques or by overgrazing. Overused soil can lose its nutrients and become infertile. Plants can't grow in soil that is infertile.

Most farming methods can increase the rate at which soil erodes. For example, plowing loosens topsoil and removes plants that hold the soil in place. The plowed topsoil is more easily blown or washed away than the unplowed topsoil is.

Soil Erosion

erosion the process by which wind, water, ice, or gravity transport soil and sediment from one location to another

When soil is left unprotected, it can be exposed to erosion. **Erosion** is the process by which wind, water, or gravity transport soil and sediment from one location to another. **Figure 3** shows Providence Canyon, which was formed from the erosion of soil when trees were cut down to clear land for farming. Roots from plants and trees are like anchors to the soil. Roots keep topsoil from being eroded. Therefore, plants and trees protect the soil. Taking care of vegetation helps take care of soil.

Reading Check **What role does vegetation play in reducing soil erosion?**

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Salinization

The accumulation of salts in the soil is known as **salinization.** Salinization is a major problem in parts of the world where rainfall amounts are low and the soil is naturally salty. In these areas, water used for irrigation is salty. So, when irrigation water evaporates from farmland, salt is left behind. In time, the soil may become so salty that plants cannot grow in it.

salinization the accumulation of salts in soil

Soil-Conservation Methods

A number of soil-conservation methods that protect topsoil are available to farmers. Some methods, such as contour plowing, terracing, and no-till farming, are used to reduce soil erosion. Crop rotation is a method that is used to slow nutrient depletion and reduce damage caused by insect pests. Finally, farmers can restore nutrients to soil by planting cover crops.

Contour Plowing and Terracing

If farmers plowed rows so that the rows ran up and down hills, what might happen during a heavy rain? The rows would channel the rainwater down the hill, which would erode the soil. To prevent erosion from happening in this way, a farmer could plow across the slope of the hills instead of up and down the slope. This method of soil conservation is called *contour plowing*. In contour plowing, the rows act as a series of dams instead of a series of rivers. If the hills are very steep, farmers can use a soil-conservation method known as *terracing*. Terracing changes one steep field into a series of small, flat fields. **Figure 4** illustrates the contour-plowing and terracing methods of soil conservation.

Figure 4 Contour Plowing and Terracing

Contour plowing helps prevent erosion from heavy rains.

Terracing prevents erosion from heavy rains on steep hills.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 5 *George Washington Carver taught soil-conservation methods to farmers.*

Crop Rotation

One way to slow down nutrient depletion is through *crop rotation*. If the same crop is grown year after year in the same field, certain nutrients become depleted. To slow this process, a farmer can plant different crops. A different crop will use up fewer nutrients or different nutrients from the soil.

Another benefit to practicing crop rotation is that insect pests cause less damage to crops. How does crop rotation decrease insect damage? The answer is relatively simple. Most insect pests eat one or only a few kinds of plants. One example of such a pest is the tomato hornworm. If farmers plant tomatoes on the same land year after year, the hornworm population grows rapidly and the tomato crop will be destroyed. However, if a different crop is planted on the same land every other year, the hornworms will not find food and will die.

Cover Crops

In the southern United States, during the early 1900s, the soil had become nutrient poor by the farming of only one crop, cotton. George Washington Carver, the scientist shown in **Figure 5,** urged farmers to plant soybeans and peanuts instead of cotton. Some plants, such as soybeans and peanuts, shown in **Figure 6,** helped to restore important nutrients to the soil. These plants are called cover crops. *Cover crops* are crops that are planted between harvests to replace certain nutrients and prevent erosion. Cover crops prevent erosion by providing cover from wind and rain.

✓ ***Reading Check*** **What can soybeans and peanuts do for nutrient-poor soil?**

Math Practice

Making Soil

Suppose it takes 500 years for 2 cm of new soil to form in a certain area. But the soil is eroding at a rate of 1 mm per year. Is the soil eroding faster than it can be replaced? Explain.

Figure 6 *Soybeans are a cover crop which restores nutrients to soil.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

No-Till Farming

In a soil-conservation method known as *no-till farming,* a farmer harvests a crop without turning over the soil. As shown in **Figure 7,** the farmer simply leaves the remains of a newly harvested crop on the ground and plants the next crop in these remains. As the new crop develops, the remains of the first crop hold the soil in place. Water runoff is reduced, and soil erosion is slowed by the cover provided by the remains of the first crop.

Compared with other farming methods, no-till farming saves time. Unfortunately, no-till farming is not suitable for all crops.

Figure 7 *No-till farming prevents erosion by providing cover that reduces water runoff.*

SECTION Review

Summary

- Soil is important for plants to grow, for animals to live in, and for water to be stored.
- Soil, water, plants, and the atmosphere are all parts of a natural cycle.
- If left unprotected, soil can be exposed to erosion.
- Contour plowing and terracing prevent soil erosion by keeping water from running directly downhill.
- Crop rotation slows nutrient depletion and reduces insect damage.
- Cover crops restore nutrients to soil and prevent soil erosion.
- No-till farming reduces water runoff and slows soil erosion.

Using Key Terms

1. In your own words, write a definition for each of the following terms: *soil conservation, erosion,* and *salinization.*

Understanding Key Ideas

2. What are three important benefits that soil provides?
3. Practicing which of the following soil-conservation techniques will replace nutrients in the soil?
   a. cover crop use
   b. no-till farming
   c. terracing
   d. contour plowing
4. List two ways in which soils can be damaged.
5. Describe two soil-conservation methods that prevent downhill soil erosion.
6. Explain two ways in which crop rotation benefits soils.
7. List two reasons that farmers plant cover crops.
8. Explain how no-till farming slows soil erosion.

Math Skills

9. Suppose it takes 500 years to form 2 cm of new soil without erosion. If a farmer needs at least 35 cm of soil to plant a particular crop, how many years will the farmer need to wait before planting his or her crop?

Critical Thinking

10. **Applying Concepts** Why do land animals, even meat eaters, depend on soil to survive?
11. **Making Predictions** How would drought affect the interrelationship between soil, water, plants, and the atmosphere?

SCILINKS® NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Soil Conservation
SciLinks code: HSM1409

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Using Scientific Methods

Model-Making Lab

Rockin' Through Time

Wind, water, and gravity constantly change rocks. As wind and water rush over the rocks, the rocks may be worn smooth. As rocks bump against one another, their shapes change. The form of mechanical weathering that occurs as rocks collide and scrape together is called *abrasion*. In this activity, you will shake some pieces of limestone to model the effects of abrasion.

OBJECTIVES

Design a model to understand how abrasion breaks down rocks.

Evaluate the effects of abrasion.

MATERIALS

- bottle, plastic, wide-mouthed, with lid, 3 L
- graph paper or computer
- markers
- pieces of limestone, all about the same size (24)
- poster board
- tap water

SAFETY

Ask a Question

1. How does abrasion break down rocks? How can I use this information to identify rocks that have been abraded in nature?

Form a Hypothesis

2. Formulate a hypothesis that answers the questions above.

Test the Hypothesis

3. Copy the chart on the next page onto a piece of poster board. Allow enough space to place rocks in each square.
4. Lay three of the limestone pieces on the poster board in the area marked "0 shakes." Be careful not to bump the poster board after you have added the rocks.
5. Place the remaining 21 rocks in the 3 L bottle. Then, fill the bottle halfway with water.
6. Close the lid of the bottle securely. Shake the bottle vigorously 100 times.
7. Remove three rocks from the bottle, and place them on the poster board in the box that indicates the number of times the rocks have been shaken.
8. Repeat steps 6 and 7 six times until all of the rocks have been added to the board.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Analyze the Results

1. **Examining Data** Describe the surface of the rocks that you placed in the area marked "0 shakes." Are they smooth or rough?
2. **Describing Events** How did the shape of the rocks change as you performed this activity?
3. **Constructing Graphs** Using graph paper or a computer, construct a graph, table, or chart that describes how the shapes of the rocks changed as a result of the number of times they were shaken.

Rocks Table	
0 shakes	100 shakes
200 shakes	300 shakes
400 shakes	500 shakes
600 shakes	700 shakes

Draw Conclusions

4. **Drawing Conclusions** Why did the rocks change?
5. **Evaluating Results** How did the water change during the activity? Why did it change?
6. **Making Predictions** What would happen if you used a much harder rock, such as granite, for this experiment?
7. **Interpreting Information** How do the results of this experiment compare with what happens in a river?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Chapter Review

USING KEY TERMS

1 In your own words, write a definition for each of the following terms: *abrasion* and *soil texture*.

2 Use each of the following terms in a separate sentence: *soil conservation* and *erosion*.

For each pair of terms, explain how the meanings of the terms differ.

3 *mechanical weathering* and *chemical weathering*

4 *soil* and *parent rock*

UNDERSTANDING KEY IDEAS

Multiple Choice

5 Which of the following processes is a possible effect of water?

a. mechanical weathering
b. chemical weathering
c. abrasion
d. All of the above

6 In which climate would you find the fastest rate of chemical weathering?

a. a warm, humid climate
b. a cold, humid climate
c. a cold, dry climate
d. a warm, dry climate

7 Which of the following properties does soil texture affect?

a. soil pH
b. soil temperature
c. soil consistency
d. None of the above

8 Which of the following properties describes a soil's ability to supply nutrients?

a. soil structure
b. infiltration
c. soil fertility
d. consistency

9 Soil is important because it provides

a. housing for animals.
b. nutrients for plants.
c. storage for water.
d. All of the above

10 Which of the following soil conservation techniques prevents erosion?

a. contour plowing
b. terracing
c. no-till farming
d. All of the above

Short Answer

11 Describe the two major types of weathering.

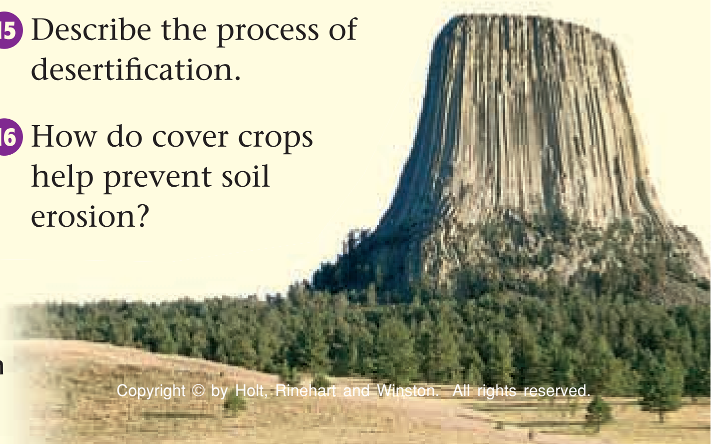
12 Why must farmers monitor soil temperature?

13 Why is soil in temperate forests thick and fertile?

14 What can happen to soil when soil conservation is not practiced?

15 Describe the process of desertification.

16 How do cover crops help prevent soil erosion?



Copyright © by Holt, Rinehart and Winston. All rights reserved.

CRITICAL THINKING

17. **Concept Mapping** Use the following terms to create a concept map: *weathering, chemical weathering, mechanical weathering, abrasion, ice wedging, oxidation,* and *soil*.

18. **Analyzing Processes** Heat generally speeds up chemical reactions. But weathering, including chemical weathering, is usually slowest in hot, dry climates. Why?

19. **Making Inferences** Mechanical weathering, such as ice wedging, increases surface area by breaking larger rocks into smaller rocks. Draw conclusions about how mechanical weathering can affect the rate of chemical weathering.

20. **Evaluating Data** A scientist has a new theory. She believes that climates that receive heavy rains all year long have thin topsoil. Given what you have learned, decide if the scientist's theory is correct. Explain your answer.

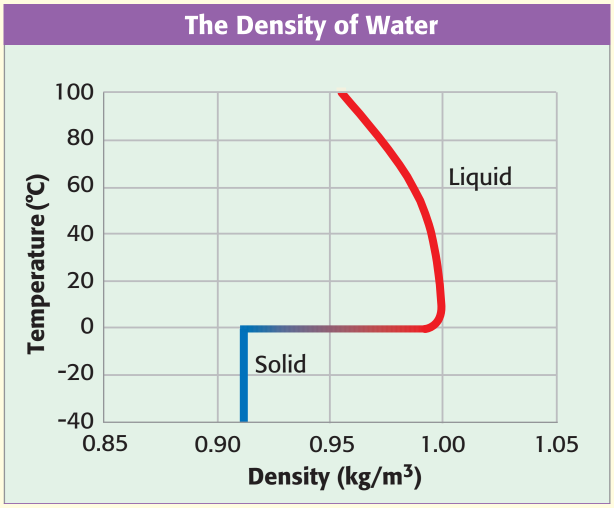
21. **Analyzing Processes** What forms of mechanical and chemical weathering would be most common in the desert? Explain your answer.

22. **Applying Concepts** If you had to plant a crop on a steep hill, what soil conservation techniques would you use to prevent erosion?

23. **Making Comparisons** Compare the weathering processes in a warm, humid climate with those in a dry, cold climate.

INTERPRETING GRAPHICS

The graph below shows how the density of water changes when temperature changes. The denser a substance is, the less volume it occupies. In other words, as most substances get colder, they contract and become denser. But water is unlike most other substances. When water freezes, it expands and becomes less dense. Use the graph to answer the questions that follow.



24. Which has the greater density: water at 40°C or water at –20°C?

25. How would the line in the graph look if water behaved like most other liquids?

26. Which substance would be a more effective agent of mechanical weathering: water or another liquid? Why?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Standardized Test Preparation

EOG Prep

READING

Read each of the passages below. Then, answer the questions that follow each passage.

Passage 1 Earthworms are very important for forming soil. As they search for food by digging tunnels in the soil, they expose rocks and minerals to the effects of weathering. Over time, this process makes new soil. And as the worms dig tunnels, they mix the soil, which allows air and water and smaller organisms to move deeper into the soil. Worms have huge appetites. They eat organic matter and other materials in the soil. One earthworm can eat an amount equal to about half its body weight each day! Eating all of that food means that earthworms leave behind a lot of waste. Earthworm wastes, called *castings,* are very high in nutrients and make excellent natural fertilizer. Castings enrich the soil and enhance plant growth.

1. In the passage, what does *enhance* mean?
- **A** to weaken
- **B** to improve
- **C** to smooth out
- **D** to decrease

2. According to the passage, the earthworms
- **F** eat organic matter and other materials in soil.
- **G** do not have much of an appetite.
- **H** love to eat castings.
- **I** cannot digest organic matter in soil.

3. Which of the following statements is a fact according to the passage?
- **A** Earthworms are not important for forming soil.
- **B** Earthworms only eat organic matter in the soil.
- **C** An earthworm can eat an amount that equals half its body weight each day.
- **D** Earthworms eat little food but leave behind a lot of waste.

Passage 2 Worms are not the only living things that help create soil. Plants also play a part in the weathering process. As the roots of plants grow and seek out water and nutrients, they help break large rock fragments into smaller ones. Have you ever seen a plant growing in a crack in the sidewalk? As the plant grows, its roots spread into tiny cracks in the sidewalk. These roots apply pressure to the cracks, and over time, the cracks get bigger. As the plants make the cracks bigger, ice wedging can occur more readily. As the cracks expand, more water runs into them. When the water freezes, it expands and presses against the walls of the crack, which makes the crack even larger. Over time, the weathering caused by water, plants, and worms helps break down rock to form soil.

1. How do plants make it easier for ice wedging to occur?
- **A** Plant roots block the cracks and don't allow water to enter.
- **B** Plant roots provide moisture to cracks.
- **C** Plant roots make the cracks larger, which allows more water to enter the cracks.
- **D** Plants absorb excess water from cracks.

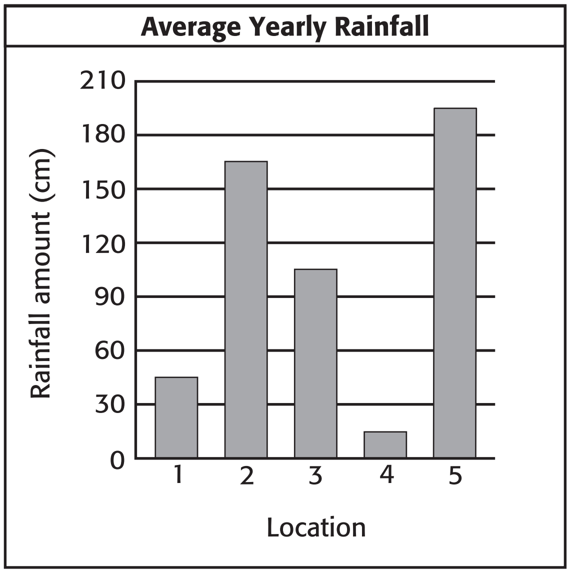
2. For ice wedging to occur,
- **F** water in cracks must freeze.
- **G** plant roots must widen cracks.
- **H** acid is needed.
- **I** water is not needed.

3. Which of the following statements is a fact according to the passage?
- **A** Plant roots can strangle earthworms.
- **B** Earthworms eat plant roots.
- **C** Plant roots cannot crack sidewalks.
- **D** Plant roots break large rock fragments into smaller ones.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

INTERPRETING GRAPHICS

The graph below shows the average yearly rainfall in five locations. Use the graph below to answer the questions that follow.



1. Which location has the **most** average yearly rainfall?

A 1
B 2
C 4
D 5

2. At which location would you expect to find the **most** chemical weathering?

F 1
G 3
H 4
I 5

3. At which location would you expect to find the **least** amount of chemical weathering?

A 2
B 3
C 4
D 5

MATH

Read each question below, and choose the best answer.

1. If an earthworm that weighs 1.5 g eats an amount equal to half its body weight in a day, how much does the earthworm eat in 1 week?

A 10.5 g
B 7 g
C 5.25 g
D 1.5 g

2. Calculate the surface area of a cube that measures 3 cm by 3 cm.

F 9 cm
G 9 cm^2
H 54 cm
I 54 cm^2

3. If a mountain peak weathers away 2 cm every 6 years, how many years will the mountain peak take to weather away 1 m?

A 8 years
B 12 years
C 180 years
D 300 years

4. The rock ledge that lies under a waterfall erodes about 3 cm each year. How much of the rock will erode over a period of 18 months?

F 4.5 cm
G 6 cm
H 21 cm
I 54 cm

5. A garden shop charges $0.30 for each ground-cover seedling. How many seedlings can you buy for $6.00?

A 5 seedlings
B 18 seedlings
C 20 seedlings
D 200 seedlings

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Science in Action

Science, Technology, and Society

Flying Fertilizer

Would you believe that dust from storms in large deserts can be transported over the oceans to different continents? Dust from the Gobi Desert in China has traveled all the way to Hawaii! In many cases, the dust is a welcome guest. Iron in dust from the Sahara, a desert in Africa, fertilizes the canopies of South American rain forests. In fact, research has shown that the canopies of Central and South American rain forests get much of their nutrients from dust from the Sahara!

Social Studies ACTIVITY

Find pictures on the Internet or in magazines that show how people in rain forests live. Make a poster by using the pictures you find.

Scientific Discoveries

Strange Soil

Mysterious patterns of circles, polygons, and stripes were discovered in the soil in remote areas in Alaska and the Norwegian islands. At first, scientists were puzzled by these strange designs in remote areas. Then, the scientists discovered that these patterns were created by the area's weathering process, which includes cycles of freezing and thawing. When the soil freezes, the soil expands. When the soil thaws, the soil contracts. This process moves and sorts the particles of the soil into patterns.

Language Arts ACTIVITY

WRITING SKILL Write a creative short story describing what life would be like if you were a soil circle on one of these remote islands.

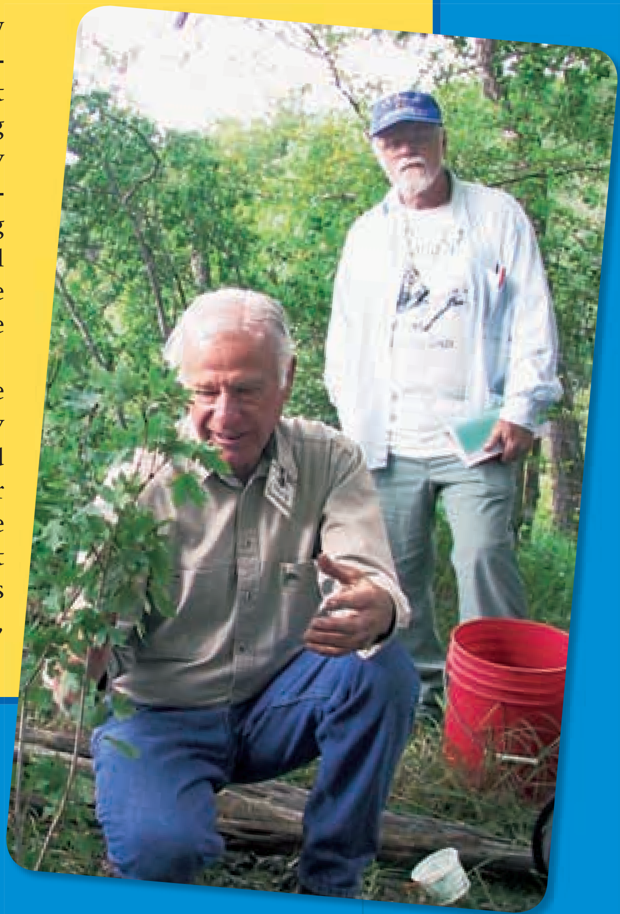
Copyright © by Holt, Rinehart and Winston. All rights reserved.

People in Science

J. David Bamberger

Habitat Restoration J. David Bamberger knows how important taking care of the environment is. Therefore, he has turned his ranch into the largest habitat restoration project in Texas. For Bamberger, restoring the habitat started with restoring the soil. One way Bamberger restored the soil was to manage the grazing of the grasslands and to make sure that grazing animals didn't expose the soil. Overgrazing causes soil erosion. When cattle clear the land of its grasses, the soil is exposed to wind and rain, which can wash the topsoil away.

Bamberger also cleared his land of most of the shrub, *juniper*. Juniper requires so much water per day that it leaves little water in the soil for the grasses and wildflowers. The change in the ranch since Bamberger first bought it in 1959 is most obvious at the fence-line border of his ranch. Beyond the fence is a small forest of junipers and little other vegetation. On Bamberger's side, the ranch is lush with grasses, wildflowers, trees, and shrubs.



Math ACTIVITY

Bamberger's ranch is 2,300 hectares. There are 0.405 hectares in 1 acre. How many acres is Bamberger's ranch?

To learn more about these Science in Action topics, visit go.hrw.com and type in the keyword HZ5WSFF.

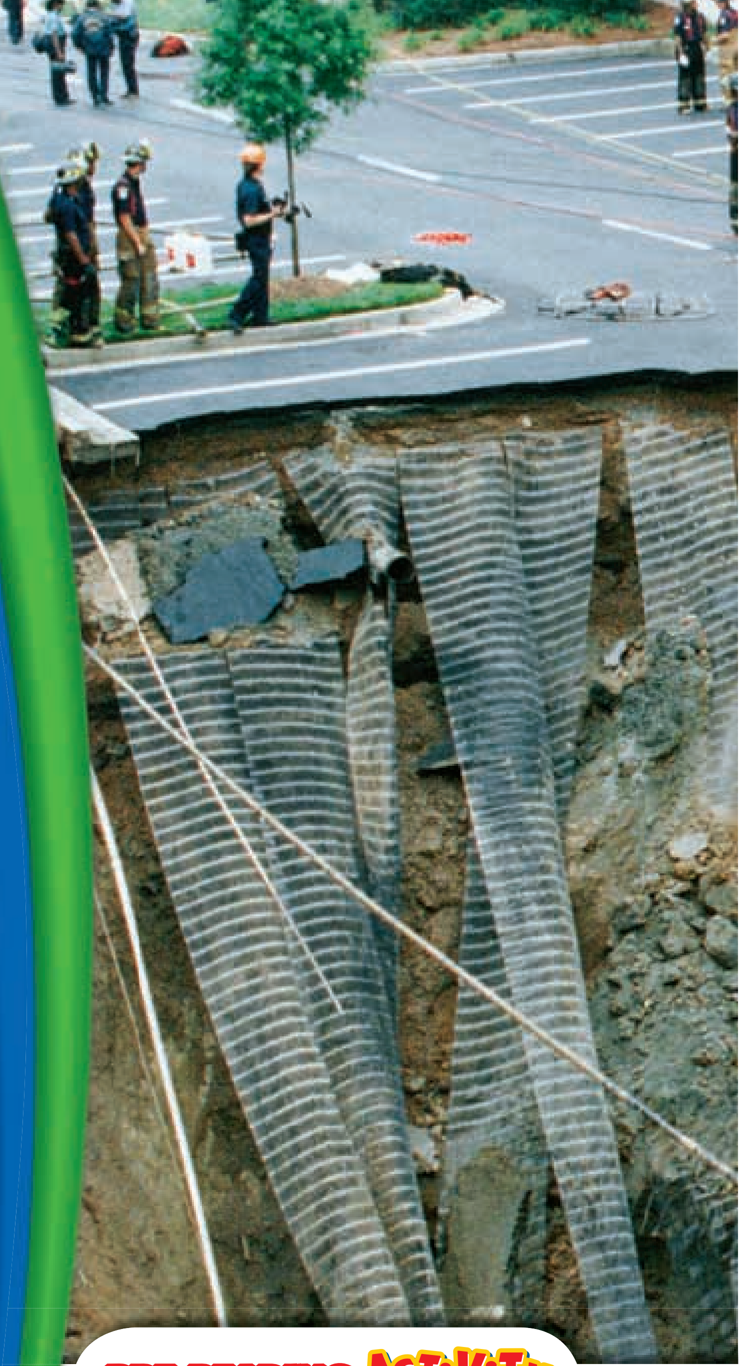
Current Science

Check out Current Science® articles related to this chapter by visiting go.hrw.com. Just type in the keyword HZ5CS10.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

8

Agents of Erosion and Deposition



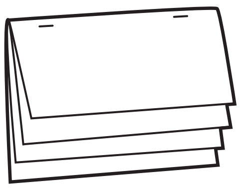
About the PHOTO

The results of erosion can often be dramatic. For example, this sinkhole formed in a parking lot in Atlanta, Georgia, when water running underground eventually caused the surface of the land to collapse.

PRE-READING ACTIVITY

FOLDNOTES

Layered Book Before you read the chapter, create the FoldNote entitled "The Layered Book" described in the **Study Skills** section of the Appendix. Label the tabs of the layered book with "Shoreline erosion and deposition," "Wind erosion and deposition," and "Erosion and deposition by ice." As you read the chapter, write information you learn about each category under the appropriate tab.



Copyright © by Holt, Rinehart and Winston. All rights reserved.

START-UP ACTIVITY

Making Waves

Above ground or below, water plays an important role in the erosion and deposition of rock and soil. A shoreline is a good example of how water shapes the Earth's surface by erosion and deposition. Did you know that shorelines are shaped by crashing waves? Build a model shoreline, and see for yourself!

Procedure

1. Make a shoreline by adding **sand** to one end of a **washtub**. Fill the washtub with **water** to a depth of 5 cm. Sketch the shoreline profile (side view), and label it "A."
2. Place a **block** at the end of the washtub opposite the beach.
3. Move the block up and down very slowly to create small waves for 2 min. Sketch the new shoreline profile, and label it "B."
4. Now, move the block up and down more rapidly to create large waves for 2 min. Sketch the new shoreline profile, and label it "C."

Analysis

1. Compare the three shoreline profiles. What is happening to the shoreline?
2. How do small waves and large waves erode the shoreline differently?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 1

Shoreline Erosion and Deposition

READING WARM-UP

Objectives

- Explain how energy from waves affects a shoreline.
- Identify six shoreline features created by wave erosion.
- Explain how wave deposits form beaches.
- Describe how sand moves along a beach.

Terms to Learn

shoreline
beach

READING STRATEGY

Reading Organizer As you read this section, create an outline of the section. Use the headings from the section in your outline.

Think about the last time you were at a beach. Where did all of the sand come from?

Two basic ingredients are necessary to make sand: rock and energy. The rock is usually available on the shore. The energy is provided by waves that travel through water. When waves crash into rocks over long periods of time, the rocks are broken down into smaller and smaller pieces until they become sand.

As you read on, you will learn how wave erosion and deposition shape the shoreline. A **shoreline** is simply the place where land and a body of water meet. Waves usually play a major role in building up and breaking down the shoreline.

Wave Energy

As the wind moves across the ocean surface, it produces ripples called *waves*. The size of a wave depends on how hard the wind is blowing and how long the wind blows. The harder and longer the wind blows, the bigger the wave.

The wind that results from summer hurricanes and severe winter storms produces large waves that cause dramatic shoreline erosion. Waves may travel hundreds or even thousands of kilometers from a storm before reaching the shoreline. Some of the largest waves to reach the California coast are produced by storms as far away as Australia. So, the California surfer in **Figure 1** can ride a wave that formed on the other side of the Pacific Ocean!

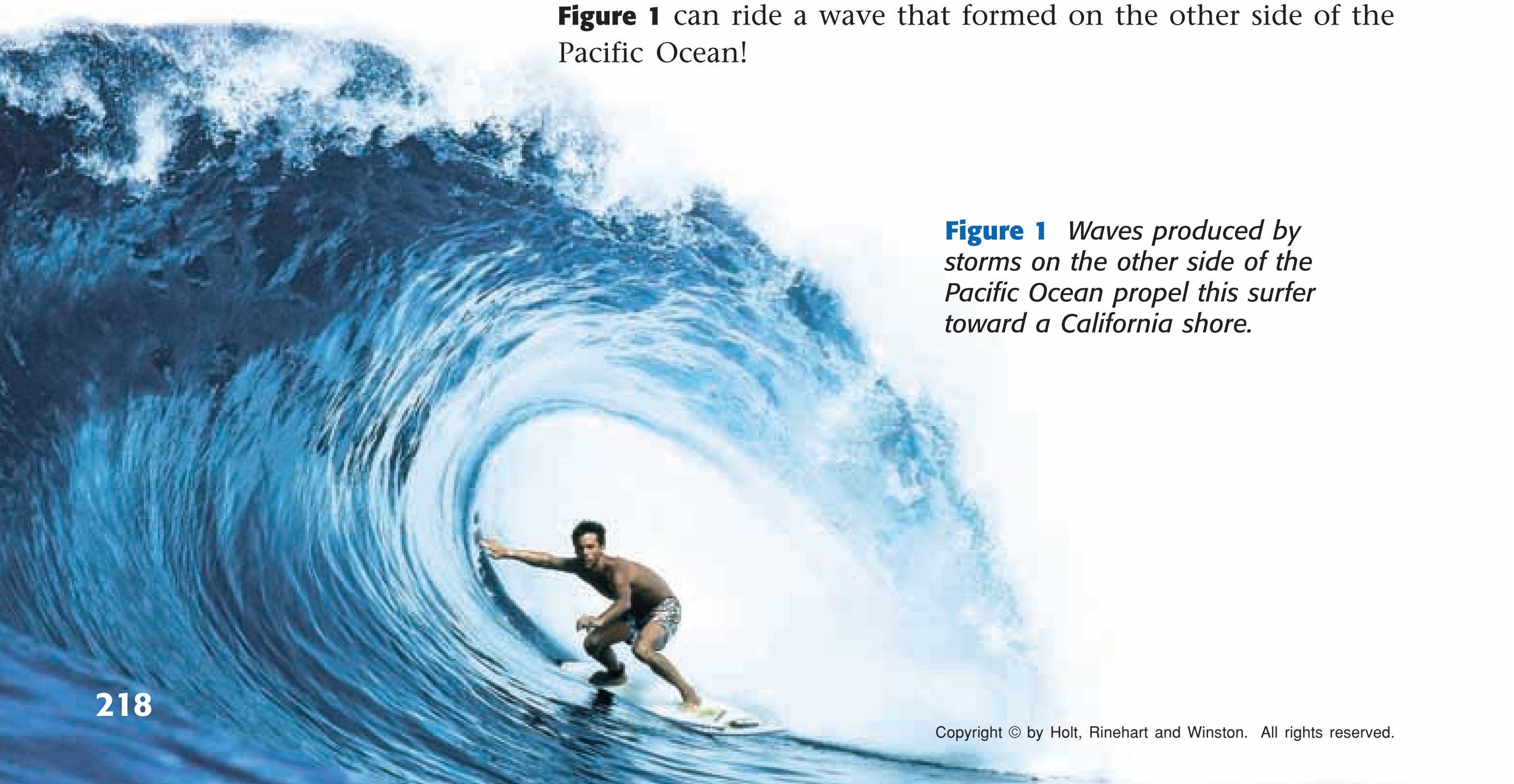


Figure 1 *Waves produced by storms on the other side of the Pacific Ocean propel this surfer toward a California shore.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Wave Trains

When you drop a pebble into a pond, is there just one ripple? Of course not. Waves, like ripples, don't move alone. As shown in **Figure 2,** waves travel in groups called *wave trains*. As wave trains move away from their source, they travel through the ocean water uninterrupted. But when waves reach shallow water, the bottom of the wave drags against the sea floor, slowing the wave down. The upper part of the wave moves more rapidly and grows taller. When the top of the wave becomes so tall that it cannot support itself, it begins to curl and break. These breaking waves are known as *surf*. Now you know how surfers got their name. The *wave period* is the time interval between breaking waves. Wave periods are usually 10 to 20 s long.

Figure 2 *Because waves travel in wave trains, they break at regular intervals.*

The Pounding Surf

Look at **Figure 3,** and you will get an idea of how sand is made. A tremendous amount of energy is released when waves break. A crashing wave can break solid rock and throw broken rocks back against the shore. As the rushing water in breaking waves enters cracks in rock, it helps break off large boulders and wash away fine grains of sand. The loose sand picked up by waves wears down and polishes coastal rocks. As a result of these actions, rock is broken down into smaller and smaller pieces that eventually become sand.

Reading Check **How do waves help break down rock into sand?** (*See the Appendix for answers to Reading Checks.*)

shoreline the boundary between land and a body of water

Math Practice

Counting Waves

If the wave period is 10 s, approximately how many waves reach a shoreline in a day? (Hint: Calculate how many waves occur in an hour, and multiply that number by the number of hours in a day.)

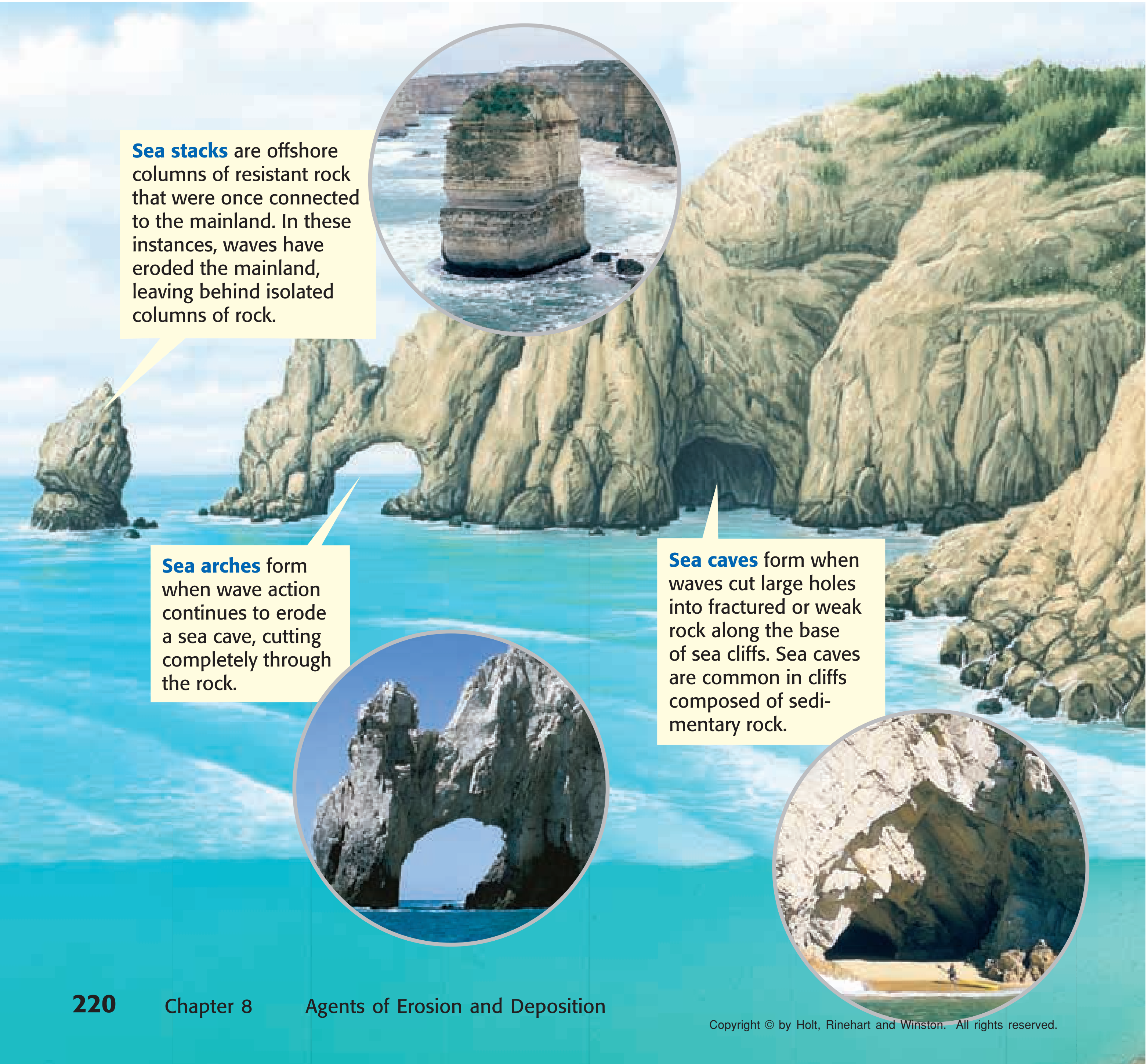
Figure 3 *Breaking waves crash against the rocky shore, releasing their energy.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Wave Erosion

Wave erosion produces a variety of features along a shoreline. *Sea cliffs* are formed when waves erode and undercut rock to produce steep slopes. Waves strike the base of the cliff, which wears away the soil and rock and makes the cliff steeper. The rate at which the sea cliffs erode depends on the hardness of the rock and the energy of the waves. Sea cliffs made of hard rock, such as granite, erode very slowly. Sea cliffs made of soft rock, such as shale, erode more rapidly, especially during storms.

Figure 4 **Coastal Landforms Created by Wave Erosion**

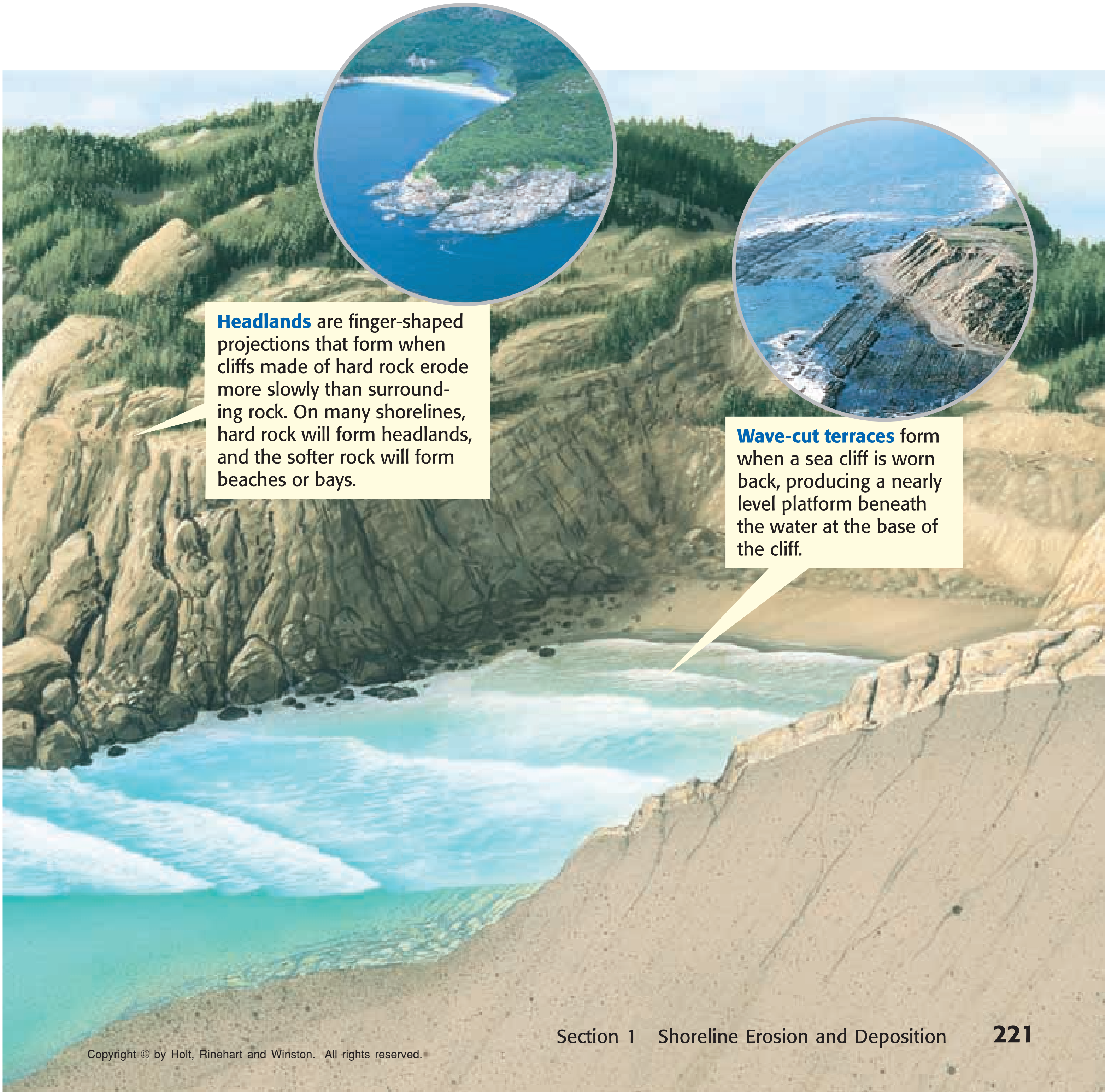


Copyright © by Holt, Rinehart and Winston. All rights reserved.

Shaping a Shoreline

Much of the erosion responsible for landforms you might see along the shoreline takes place during storms. Large waves generated by storms release far more energy than normal waves do. This energy is so powerful that it is capable of removing huge chunks of rock. **Figure 4** shows some of the major landscape features that result from wave erosion.

Reading Check **Why are large waves more capable of removing large chunks of rock from a shoreline than normal waves are?**



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Wave Deposits

Waves carry a variety of materials, including sand, rock fragments, dead coral, and shells. Often, this material is deposited on a shoreline, where it forms a beach.

Beaches

You would probably recognize a beach if you saw one. However, scientifically speaking, a **beach** is any area of the shoreline made up of material deposited by waves. Some beach material is also deposited by rivers.

Compare the beaches shown in **Figure 5.** Notice that the colors and textures vary. They vary because the type of material found on a beach depends on its source. Light-colored sand is the most common beach material. Much of this sand comes from the mineral quartz. But not all beaches are made of light-colored sand. For example, on many tropical islands, such as the Virgin Islands, beaches are made of fine, white coral material. Some Florida beaches are made of tiny pieces of broken seashells. Black sand beaches in Hawaii are made of eroded volcanic lava. In areas where stormy seas are common, beaches are made of pebbles and boulders.

Reading Check **Where does beach material come from?**

Figure 5 *Beaches are made of different types of material deposited by waves.*

beach an area of the shoreline made up of material deposited by waves

Wave Angle and Sand Movement

The movement of sand along a beach depends on the angle at which the waves strike the shore. Most waves approach the beach at a slight angle and retreat in a direction more perpendicular to the shore. This movement of water is called a longshore current. A *longshore current* is a water current that moves the sand in a zigzag pattern along the beach, as you can see in **Figure 6.**

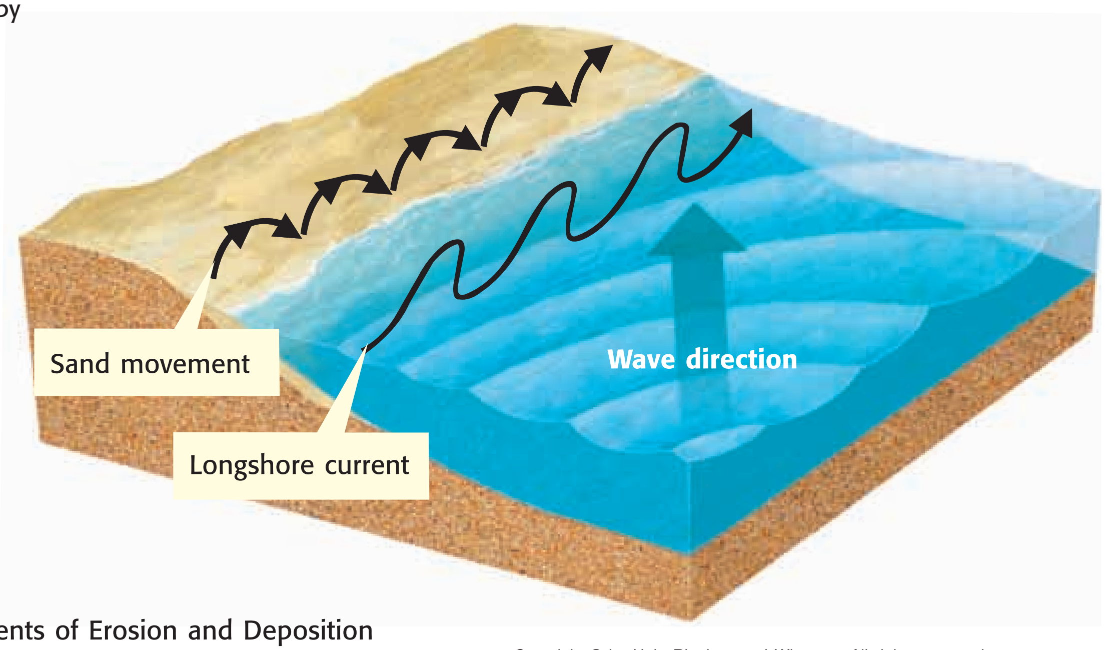


Figure 6 *When waves strike the shoreline at an angle, sand migrates along the beach in a zigzag path.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Offshore Deposits

Waves moving at an angle to the shoreline push water along the shore and create longshore currents. When waves erode material from the shoreline, longshore currents can transport and deposit this material offshore, which creates landforms in open water. A *sandbar* is an underwater or exposed ridge of sand, gravel, or shell material. A *barrier spit* is an exposed sandbar that is connected to the shoreline. Cape Cod, Massachusetts, shown in **Figure 7,** is an example of a barrier spit. A barrier island is a long, narrow island usually made of sand that forms offshore parallel to the shoreline.

Figure 7 *A barrier spit, such as Cape Cod, Massachusetts, occurs when an exposed sandbar is connected to the shoreline.*

SECTION Review

Summary

- As waves break against a shoreline, rock is broken down into sand.
- Six shoreline features created by wave erosion include sea cliffs, sea stacks, sea caves, sea arches, headlands, and wave-cut terraces.
- Beaches are made from material deposited by waves.
- Longshore currents cause sand to move in a zigzag pattern along the shore.

Using Key Terms

Complete each of the following sentences by choosing the correct term from the word bank.

shoreline beach

1. A ___ is an area made up of material deposited by waves.
2. An area in which land and a body of water meet is a ___.

Understanding Key Ideas

3. Which of the following is a result of wave deposition?
   a. sea arch
   b. sea cave
   c. barrier spit
   d. headland
4. How do wave deposits affect a shoreline?
5. Describe how sand moves along a beach.
6. What are six shoreline features created by wave erosion?
7. How can the energy of waves traveling through water affect a shoreline?
8. Would a small wave or a large wave have more energy? Explain your answer.

Math Skills

9. Imagine that there is a large boulder on the edge of a shoreline. If the wave period is 15 s long, how many times is the boulder hit in a year?

Critical Thinking

10. **Applying Concepts** Not all beaches are made from light-colored sand. Explain why this statement is true.
11. **Making Inferences** How can severe storms over the ocean affect shoreline erosion and deposition?
12. **Making Predictions** How could a headland change in 250 years? Describe some of the features that may form.

SCILINKS® NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Wave Erosion
SciLinks code: HSM1638

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 2

Wind Erosion and Deposition

READING WARM-UP

Objectives

- Explain why some areas are more affected by wind erosion than other areas are.
- Describe the process of saltation.
- Identify three landforms that result from wind erosion and deposition.
- Explain how dunes move.

Terms to Learn

saltation
deflation
abrasion
loess
dune

READING STRATEGY

Reading Organizer As you read this section, make a table comparing deflation and abrasion.

Have you ever been working outside and had a gusty wind blow an important stack of papers all over the place?

Do you remember how fast and far the papers traveled and how long it took to pick them up? Every time you caught up with them, they were on the move again. If this has happened to you, then you have seen how wind erosion works. As an agent of erosion, the wind removes soil, sand, and rock particles and transports them from one place to another.

Certain locations are more vulnerable to wind erosion than others. An area with little plant cover can be severely affected by wind erosion because plant roots anchor sand and soil in place. Deserts and coastlines that are made of fine, loose rock material and have little plant cover are shaped most dramatically by the wind.

The Process of Wind Erosion

Wind moves material in different ways. In areas where strong winds occur, material is moved by saltation. **Saltation** is the skipping and bouncing movement of sand-sized particles in the direction the wind is blowing. As you can see in **Figure 1,** the wind causes the particles to bounce. When moving sand grains knock into one another, some grains bounce up in the air, fall forward, and strike other sand grains. These impacts cause other grains to roll and bounce forward.

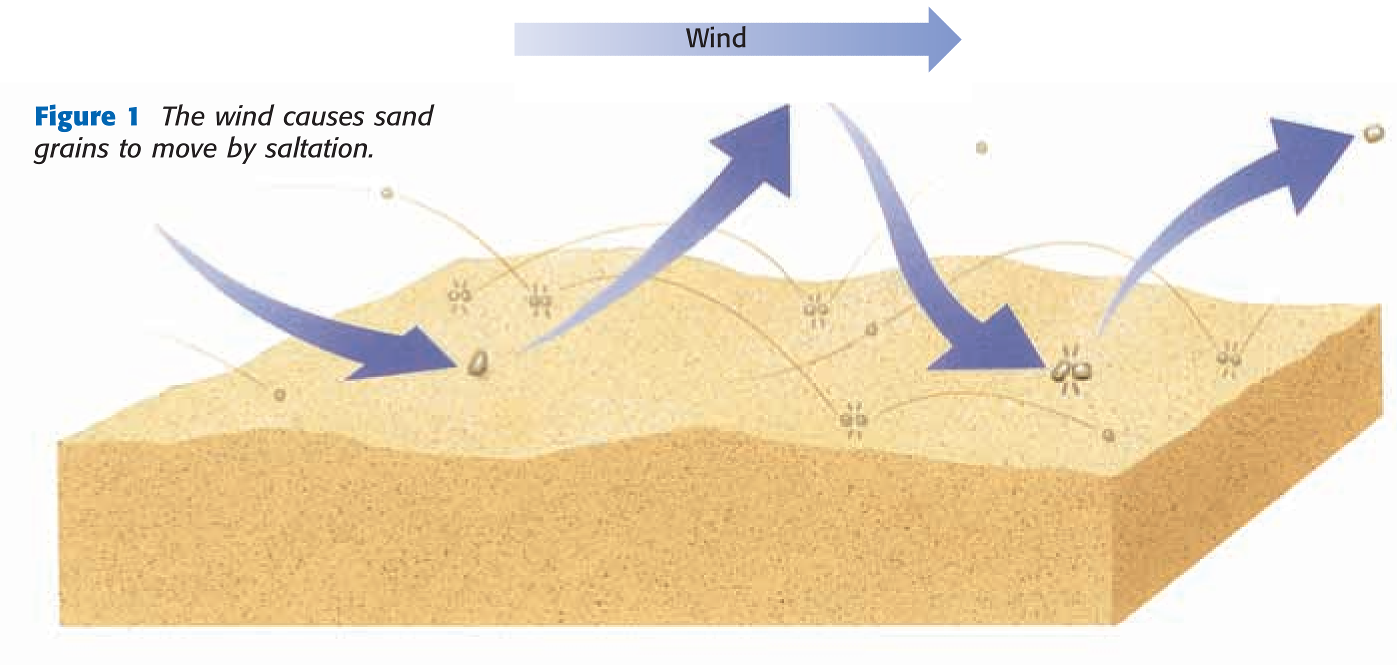


Figure 1 *The wind causes sand grains to move by saltation.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 2 *Desert pavement, such as that found in the Painted Desert in Arizona, forms when wind removes all the fine materials.*

Deflation

The removal of fine sediment by wind is called **deflation.** During deflation, wind removes the top layer of fine sediment or soil and leaves behind rock fragments that are too heavy to be lifted by the wind. Deflation may cause *desert pavement*, which is a surface consisting of pebbles and small broken rocks. An example of desert pavement is shown in **Figure 2.**

Have you ever blown on a layer of dust while cleaning off a dresser? If you have, you may have noticed that in addition to your face getting dirty, a little scooped-out depression formed in the dust. Similarly, in areas where there is little vegetation, the wind may scoop out depressions in the landscape. These depressions are called *deflation hollows*.

Reading Check **Where do deflation hollows form?** (*See the Appendix for answers to Reading Checks.*)

saltation the movement of sand or other sediments by short jumps and bounces that is caused by wind or water

deflation a form of wind erosion in which fine, dry soil particles are blown away

abrasion the grinding and wearing away of rock surfaces through the mechanical action of other rock or sand particles

Abrasion

The grinding and wearing down of rock surfaces by other rock or sand particles is called **abrasion.** Abrasion commonly happens in areas where there are strong winds, loose sand, and soft rocks. The blowing of millions of sharp sand grains creates a sandblasting effect. This effect helps to erode, smooth, and polish rocks.

Quick Lab

Making Desert Pavement

1. Spread a mixture of **dust, sand,** and **gravel** on an **outdoor table.**
2. Place an **electric fan** at one end of the table.
3. Put on **safety goggles** and a **filter mask.** Aim the fan across the sediment. Start the fan on its lowest speed. Record your observations.
4. Turn the fan to a medium speed. Record your observations.
5. Finally, turn the fan to a high speed to imitate a desert windstorm. Record your observations.
6. What is the relationship between the wind speed and the size of the sediment that is moved?
7. Does the remaining sediment fit the definition of desert pavement?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Wind-Deposited Materials

Much like rivers, the wind also carries sediment. And just as rivers deposit their loads, the wind eventually drops all the material it carries. The amount and the size of particles the wind can carry depend on the wind speed. The faster the wind blows, the more material and the heavier the particles it can carry. As wind speed slows, heavier particles are deposited first.

CONNECTION TO Language Arts

WRITING SKILL **The Dust Bowl** During the 1930s, a severe drought occurred in a section of the Great Plains that became known as the *Dust Bowl*. The wind carried so much dust that some cities left street lights on during the day. Research the Dust Bowl, and describe it in a series of three journal entries written from the perspective of a farmer.

Loess

Wind can deposit extremely fine material. Thick deposits of this windblown, fine-grained sediment are known as **loess** (LOH ES). Loess feels like the talcum powder a person may use after a shower.

Because wind carries fine-grained material much higher and farther than it carries sand, loess deposits are sometimes found far away from their source. Many loess deposits came from glacial sources during the last Ice Age. In the United States, loess is present in the Midwest, along the eastern edge of the Mississippi Valley, and in eastern Oregon and Washington.

loess very fine sediments deposited by the wind

dune a mound of wind-deposited sand that keeps its shape even though it moves

Dunes

When the wind hits an obstacle, such as a plant or a rock, the wind slows down. As it slows, the wind deposits, or drops, the heavier material. The material collects, which creates an additional obstacle. This obstacle causes even more material to be deposited, forming a mound. Eventually, the original obstacle becomes buried. The mounds of wind-deposited sand are called **dunes.** Dunes are common in sandy deserts and along the sandy shores of lakes and oceans. **Figure 3** shows a large dune in a desert area.

Figure 3 *Dunes migrate in the direction of the wind.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

The Movement of Dunes

Dunes tend to move in the direction of strong winds. Different wind conditions produce dunes in various shapes and sizes. A dune usually has a gently sloped side and a steeply sloped side, or *slip face,* as shown in **Figure 4.** In most cases, the gently sloped side faces the wind. The wind is constantly transporting material up this side of the dune. As sand moves over the crest, or peak, of the dune, it slides down the slip face, creating a steep slope.

Reading Check **In what direction do dunes move?**

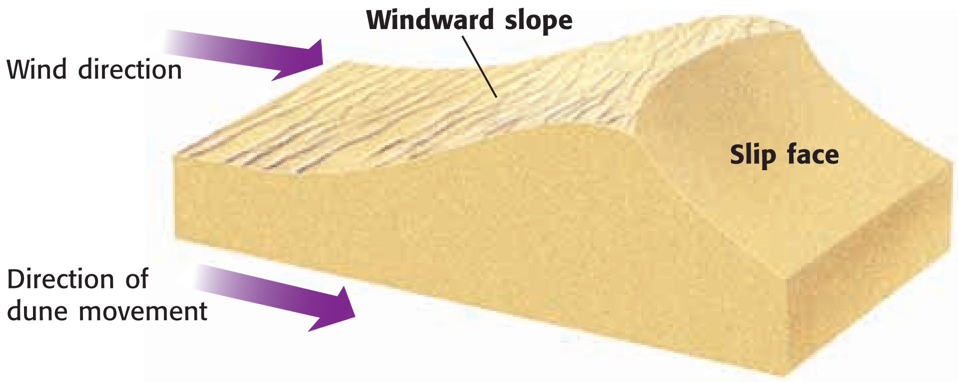


Figure 4 *Dunes are formed from material deposited by wind.*

SECTION Review

Summary

- Areas with little plant cover and desert areas covered with fine rock material are more vulnerable than other areas to wind erosion.
- Saltation is the process in which sand-sized particles move in the direction of the wind.
- Three landforms that are created by wind erosion and deposition are desert pavement, deflation hollows, and dunes.
- Dunes move in the direction of the wind.

Using Key Terms

In each of the following sentences, replace the incorrect term with the correct term from the word bank.

dune	saltation
deflation	abrasion

1. Deflation hollows are mounds of wind-deposited sand.
2. The removal of fine sediment by wind is called abrasion.

Understanding Key Ideas

3. Which of the following landforms is the result of wind deposition?
   a. deflation hollow
   b. desert pavement
   c. dune
   d. abrasion
4. Describe how material is moved in areas where strong winds blow.
5. Explain the process of abrasion.

Math Skills

6. If a dune moves 40 m per year, how far does it move in 1 day?

Critical Thinking

7. **Identifying Relationships** Explain the relationship between plant cover and wind erosion.
8. **Applying Concepts** If you climbed up the steep side of a sand dune, is it likely that you traveled in the direction the wind was blowing?

SCILINKS® NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Wind Erosion
SciLinks code: HSM1669

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 3

Erosion and Deposition by Ice

Can you imagine an ice cube that is the size of a football stadium? Well, glaciers can be even bigger than that.

READING WARM-UP

Objectives

- Explain the difference between alpine glaciers and continental glaciers.
- Describe two ways in which glaciers move.
- Identify five landscape features formed by alpine glaciers.
- Identify four types of moraines.

Terms to Learn

glacier
glacial drift
till
stratified drift

READING STRATEGY

Discussion Read this section silently. Write down questions that you have about this section. Discuss your questions in a small group.

A **glacier** is an enormous mass of moving ice. Because glaciers are very heavy and have the ability to move across the Earth's surface, they are capable of eroding, moving, and depositing large amounts of rock materials. And while you will never see a glacier chilling a punch bowl, you might one day visit some of the spectacular landscapes carved by glacial activity!

glacier a large mass of moving ice

Glaciers—Rivers of Ice

Glaciers form in areas so cold that snow stays on the ground year-round. In polar regions and at high elevations, snow piles up year after year. Over time, the weight of the snow on top causes the deep-packed snow to become ice crystals. These ice crystals eventually form a giant ice mass. Because glaciers are so massive, the pull of gravity causes them to flow slowly, like "rivers of ice." In this section, you will learn about two main types of glaciers, alpine and continental.

Alpine Glaciers

Alpine glaciers form in mountainous areas. One common type of alpine glacier is a valley glacier. Valley glaciers form in valleys originally created by stream erosion. As these glaciers slowly flow downhill, they widen and straighten the valleys into broad U shapes as shown in **Figure 1.**

Reading Check **Where do alpine glaciers form?** (*See the Appendix for answers to Reading Checks.*)

Figure 1 *Alpine glaciers start as snowfields in mountainous areas.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 2 *Eleven U.S. states were covered by ice during the last glacial ice period. Because much of the Earth's water was frozen in glaciers, sea levels fell. Blue lines show the coastline at that time.*

Continental Glaciers

Not all glaciers are true "rivers of ice." In fact, some glaciers spread across entire continents. These glaciers, called *continental glaciers*, are huge, continuous masses of ice. The largest continental glacier in the world covers almost all of Antarctica. This ice sheet is approximately one and a half times the size of the United States. It is so thick—more than 4,000 m in places—that it buries everything but the highest mountain peaks.

Glaciers on the Move

When enough ice builds up on a slope, the ice begins to move downhill. Thick glaciers move faster than thin glaciers, and the steeper the slope is, the faster the glaciers will move. Glaciers move in two ways: by sliding and by flowing. A glacier slides when its weight causes the ice at the bottom of the glacier to melt. As the water from a melting ice cube causes the ice cube to travel across a table, the water from the melting ice causes a glacier to move forward. A glacier also flows slowly as ice crystals within the glacier slip over each other. Think of placing a deck of cards on a table and then tilting the table. The top cards will slide farther than the lower cards. Similarly, the upper part of the glacier flows faster than the base.

Glacier movement is affected by climate. As the Earth cools, glaciers grow. About 10,000 years ago, a continental glacier covered most of North America, as shown in **Figure 2.** In some places, the ice sheet was several kilometers thick!

SCHOOL to HOME

The *Titanic*

WRITING SKILL An area where an ice sheet is resting on open water is called an *ice shelf.* When pieces of the ice shelf break off, they are called *icebergs.* How far do you think the iceberg that struck the *Titanic* drifted before the two met that fateful night in 1912? Together with a parent, plot on a map of the North Atlantic Ocean the route of the *Titanic* from Southampton, England, to New York. Then, plot a possible route of the drifting iceberg from Greenland to where the ship sank, just south of the Canadian island province of Newfoundland. Describe your findings in your **science journal.**

ACTIVITY

Copyright © by Holt, Rinehart and Winston. All rights reserved.

MATH PRACTICE

Speed of a Glacier

An alpine glacier is estimated to be moving forward at 5 m per day. Calculate how long the ice will take to reach a road and campground located 0.5 km from the front of the advancing glacier. (Hint: 1 km = 1,000 m)

Landforms Carved by Glaciers

Continental glaciers and alpine glaciers produce landscapes that are very different from one another. Continental glaciers smooth the landscape by scraping and eroding features that existed before the ice appeared. Alpine glaciers carve out rugged features in the mountain rocks through which they flow. **Figure 3** shows the very different landscapes that each type of glacier produces.

Alpine glaciers, such as those in the Rocky Mountains and the Alps, carve out large amounts of rock material and create spectacular landforms. **Figure 4** shows the kinds of landscape features that are sculpted by alpine glaciers.

Figure 3 **Landscapes Created by Glaciers**

Continental glaciers smooth and flatten the landscape.

Alpine glaciers carved out this rugged landscape.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 4 Landscape Features Carved by Alpine Glaciers

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Types of Glacial Deposits

glacial drift the rock material carried and deposited by glaciers

till unsorted rock material that is deposited directly by a melting glacier

stratified drift a glacial deposit that has been sorted and layered by the action of streams or meltwater

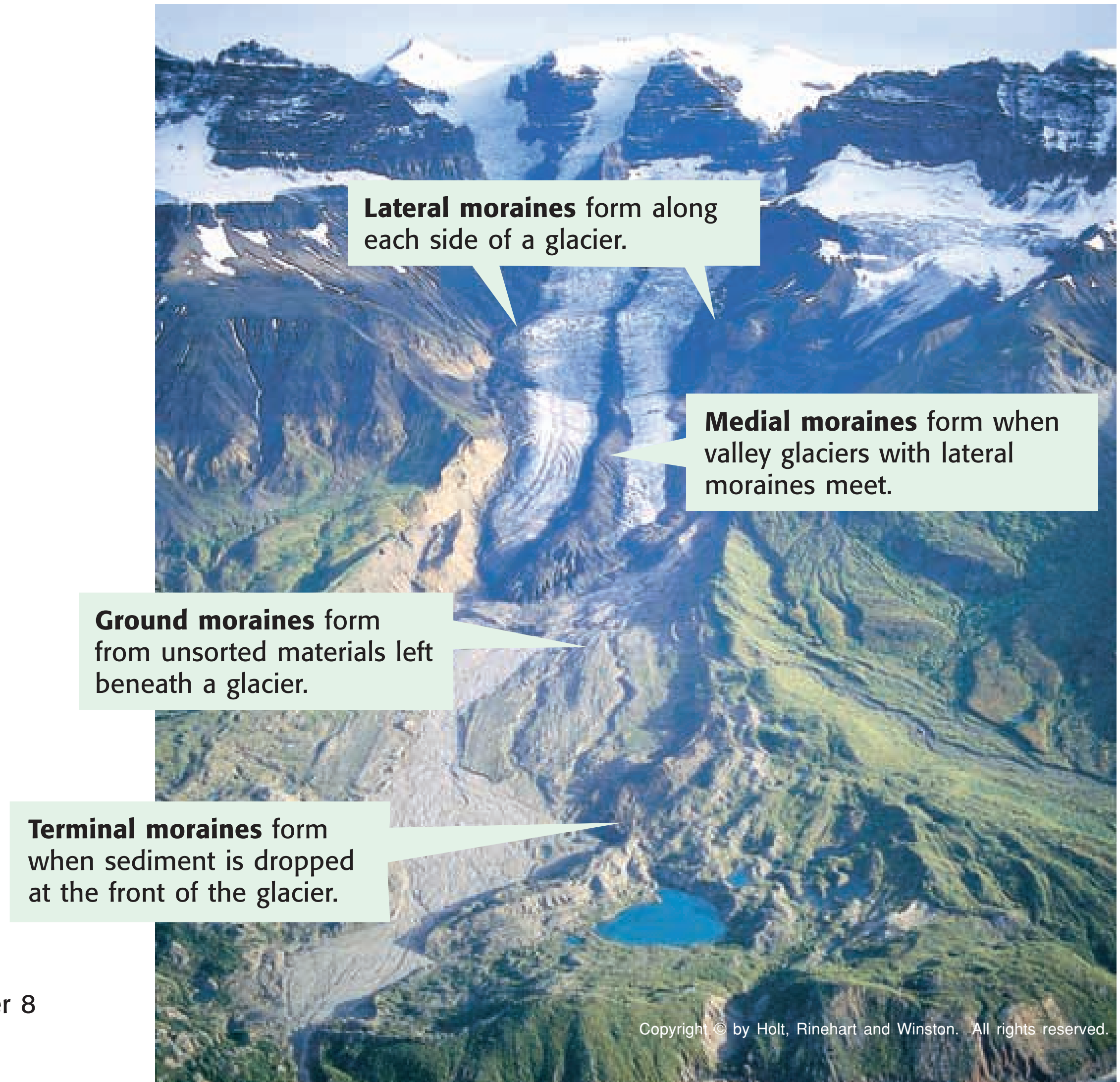
As a glacier melts, it drops all the material it is carrying. **Glacial drift** is the general term used to describe all material carried and deposited by glaciers. Glacial drift is divided into two main types, *till* and *stratified drift*.

Till Deposits

Unsorted rock material that is deposited directly by the ice when it melts is called **till.** *Unsorted* means that the till is made up of rock material of different sizes—from large boulders to fine sediment. When the glacier melts, the unsorted material is deposited on the surface of the ground.

The most common till deposits are *moraines*. Moraines generally form ridges along the edges of glaciers. Moraines are produced when glaciers carry material to the front of and along the sides of the ice. As the ice melts, the sediment and rock it is carrying are dropped, which forms different types of moraines. The various types of moraines are shown in **Figure 5.**

Figure 5 **Types of Moraines**



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Stratified Drift

When a glacier melts, streams form that carry rock material away from the shrinking glacier. A glacial deposit that is sorted into layers based on the size of the rock material is called **stratified drift.** Streams carry sorted material and deposit it in front of the glacier in a broad area called an *outwash plain*. Sometimes, a block of ice is left in the outwash plain when a glacier retreats. As the ice melts, sediment builds up around the block of ice, and a depression called a *kettle* forms. Kettles commonly fill with water to form lakes or ponds, as **Figure 6** shows.

Reading Check **Explain the difference between a till deposit and stratified drift.**

Figure 6 *Kettle lakes form in outwash plains and are common in states such as Minnesota.*

SECTION Review

Summary

- Alpine glaciers form in mountainous areas. Continental glaciers spread across entire continents.
- Glaciers can move by sliding or by flowing.
- Alpine glaciers can carve cirques, arêtes, horns, U-shaped valleys, and hanging valleys.
- Two types of glacial drift are till and stratified drift.
- Four types of moraines are lateral, medial, ground, and terminal moraines.

Using Key Terms

Complete each of the following sentences by choosing the correct term from the word bank.

glacial drift	glacier
stratified drift	till

1. A glacial deposit that is sorted into layers based on the size of the rock material is called ___.
2. ___ is all of the material carried and deposited by glaciers.
3. Unsorted rock material that is deposited directly by the ice when it melts is ___.
4. A ___ is an enormous mass of moving ice.

Understanding Key Ideas

5. Which of the following is not a type of moraine?
   a. lateral
   b. horn
   c. ground
   d. medial
6. Explain the difference between alpine and continental glaciers.
7. Name five landscape features formed by alpine glaciers.
8. Describe two ways in which glaciers move.

Math Skills

9. A recent study shows that a glacier in Alaska is melting at a rate of 23 ft per year. At what rate is the glacier melting in meters? (Hint: 1 ft = 0.3 m)

Critical Thinking

10. **Analyzing Ideas** Explain why continental glaciers smooth the landscape and alpine glaciers create a rugged landscape.
11. **Applying Concepts** How can a glacier deposit both sorted and unsorted material?
12. **Applying Concepts** Why are glaciers such effective agents of erosion and deposition?

SCILINKS® NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Glaciers
SciLinks code: HSM0675

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 4

The Effect of Gravity on Erosion and Deposition

Did you know that the Appalachian Mountains may have once been almost five times as tall as they are now? Why are they shorter now? Part of the answer lies in the effect that gravity has on all objects on Earth.

READING WARM-UP

Objectives

- Explain the role of gravity as an agent of erosion and deposition.
- Explain how angle of repose is related to mass movement.
- Describe four types of rapid mass movement.
- Describe three factors that affect creep.

Terms to Learn

mass movement
rock fall
landslide
mudflow
creep

READING STRATEGY

Prediction Guide Before reading this section, write the title of each heading in this section. Next, under each heading, write what you think you will learn.

Although you can't see it, the force of gravity is also an agent of erosion and deposition. Gravity not only influences the movement of water and ice but also causes rocks and soil to move downslope. **Mass movement** is the movement of any material, such as rock, soil, or snow, downslope. Whether mass movement happens rapidly or slowly, it plays a major role in shaping the Earth's surface.

Angle of Repose

If dry sand is piled up, it will move downhill until the slope becomes stable. The *angle of repose* is the steepest angle, or slope, at which loose material will not slide downslope. This is demonstrated in **Figure 1.** The angle of repose is different for each type of surface material. Characteristics of the surface material, such as its size, weight, shape, and moisture level, determine at what angle the material will move downslope.

mass movement a movement of a section of land down a slope

Figure 1 *If the slope on which material rests is less than the angle of repose, the material will stay in place. If the slope is greater than the angle of repose, the material will move downslope.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Rapid Mass Movement

The most destructive mass movements happen suddenly and rapidly. Rapid mass movement can be very dangerous and can destroy everything in its path.

Rock Falls

While driving along a mountain road, you may have noticed signs along the road that warn of falling rocks. A **rock fall** happens when loose rocks fall down a steep slope. Steep slopes are sometimes created to make room for a road in mountainous areas. Loosened and exposed rocks above the road tend to fall as a result of gravity. The rocks in a rock fall can range in size from small fragments to large boulders.

Landslides

Another type of rapid mass movement is a landslide. A **landslide** is the sudden and rapid movement of a large amount of material downslope. A *slump,* shown in **Figure 2,** is the most common type of landslide. Slumping occurs when a block of material moves downslope over a curved surface. Heavy rains, deforestation, construction on unstable slopes, and earthquakes increase the chances that a landslide will happen. **Figure 3** shows a landslide in India.

Reading Check **What is a slump?** (*See the Appendix for answers to Reading Checks.*)

Figure 2 *A slump is a type of landslide that occurs when a block of land becomes detached and slides downhill.*

rock fall a group of loose rocks that fall down a steep slope

landslide the sudden movement of rock and soil down a slope

Figure 3 *This landslide in Bombay, India, happened after heavy monsoon rains.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 4 *This photo shows one of the many mudflows that have occurred in California during rainy winters.*

Mudflows

A rapid movement of a large mass of mud is a **mudflow.** Mudflows happen when a large amount of water mixes with soil and rock. The water causes the slippery mass of mud to flow rapidly downslope. Mudflows commonly happen in mountainous regions when a long dry season is followed by heavy rains. Deforestation and the removal of ground cover can often result in devastating mudflows. As you can see in **Figure 4,** a mudflow can carry trees, houses, cars, and other objects that lie in its path.

mudflow the flow of a mass of mud or rock and soil mixed with a large amount of water

Lahars

Volcanic eruptions or heavy rains on volcanic ash can produce some of the most dangerous mudflows. Mudflows of volcanic origin are called *lahars*. Lahars can travel at speeds greater than 80 km/h and can be as thick as cement. On volcanoes with snowy peaks, an eruption can suddenly melt a great amount of ice. The water from the ice liquefies the soil and volcanic ash to produce a hot mudflow that rushes downslope. **Figure 5** shows the effects of a massive lahar in Japan.

Reading Check **Explain how a lahar occurs.**

Figure 5 *This lahar overtook the city of Kyushu in Japan.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Slow Mass Movement

Sometimes, you don't even notice mass movement happening. Although rapid mass movements are visible and dramatic, slow mass movements happen a little at a time. However, because slow mass movements occur more frequently, more material is moved collectively over time.

Figure 6 *Bent tree trunks are evidence that creep is happening.*

Creep

Even though most slopes appear to be stable, they are actually undergoing slow mass movement, as shown in **Figure 6.** The extremely slow movement of material downslope is called **creep.** Many factors contribute to creep. Water loosens soil and allows it to move freely. In addition, plant roots act as a wedge that forces rocks and soil particles apart. Burrowing animals, such as gophers and groundhogs, also loosen rock and soil particles. In fact, rock and soil on every slope travels slowly downhill.

creep the slow downhill movement of weathered rock material

SECTION Review

Summary

- Gravity causes rocks and soil to move downslope.
- If the slope on which material rests is greater than the angle of repose, mass movement will occur.
- Four types of rapid mass movement are rock falls, landslides, mudflows, and lahars.
- Water, plant roots, and burrowing animals can cause creep.

Using Key Terms

Complete each of the following sentences by choosing the correct term from the word bank.

creep	mass movement
mudflow	rock fall

1. A ___ occurs when a large amount of water mixes with soil and rock.

2. The extremely slow movement of material downslope is called ___.

Understanding Key Ideas

3. Which of the following is a factor that affects creep?

a. water
b. burrowing animals
c. plant roots
d. All of the above.

4. How is the angle of repose related to mass movement?

Math Skills

5. If a lahar is traveling at 80 km/h, how long will it take the lahar to travel 20 km?

Critical Thinking

6. Identifying Relationships Which types of mass movement are most dangerous to humans? Explain your answer.

7. Making Inferences How does deforestation increase the likelihood of mudflows?

SCILINKS. NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Mass Movements
SciLinks code: HSM0917

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Model-Making Lab

Gliding Glaciers

OBJECTIVES

Build a model of a glacier.

Demonstrate the effects of glacial erosion by various materials.

Observe the effect of pressure on the melting rate of a glacier.

MATERIALS

- brick (3)
- clay, modeling (2 lb)
- container, empty large margarine (3)
- freezer
- graduated cylinder, 50 mL
- gravel (1 lb)
- pan, aluminum rectangular (3)
- rolling pin, wood
- ruler, metric
- sand (1 lb)
- stopwatch
- towel, small hand
- water

A glacier is a large, moving mass of ice. Glaciers are responsible for shaping many of Earth's natural features. Glaciers are set in motion by the pull of gravity and by the gradual melting of the glacier. As a glacier moves, it changes the landscape by eroding the surface over which it passes.

Part A: Getting in the Groove

Procedure

The material that is carried by a glacier erodes Earth's surface by gouging out grooves called *striations*. Different materials have varying effects on the landscape. In this activity, you will create a model glacier with which to demonstrate the effects of glacial erosion by various materials.

1. Fill one margarine container with sand to a depth of 1 cm. Fill another margarine container with gravel to a depth of 1 cm. Leave the third container empty. Fill the containers with water.
2. Put the three containers in a freezer, and leave them there overnight.
3. Retrieve the containers from the freezer, and remove the three ice blocks from the containers.
4. Use a rolling pin to flatten the modeling clay.
5. Hold the ice block from the third container firmly with a towel, and press as you move the ice along the length of the clay. Do this three times. In a notebook, sketch the pattern that the ice block makes in the clay.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

6. Repeat steps 4 and 5 using the ice block that contains sand.
7. Repeat steps 4 and 5 using the ice block that contains gravel.

Analyze the Results

1. **Describing Events** Did any material from the clay become mixed with the material in the ice blocks? Explain.
2. **Describing Events** Was any material from the ice blocks deposited on the clay surface? Explain.
3. **Examining Data** What glacial features are represented in your clay model?

Draw Conclusions

4. **Evaluating Data** Compare the patterns formed by the three model glaciers. Do the patterns look like features carved by alpine glaciers or by continental glaciers? Explain.

Part B: Melting Away

Procedure

As the layers of ice build up and a glacier gets larger, a glacier will eventually begin to melt. The water from the melted ice allows a glacier to move forward. In this activity, you'll explore the effect of pressure on the melting rate of a glacier.

1. If possible, make three identical ice blocks without any sand or gravel in them. If that is not possible, use the ice blocks from Part A. Place one ice block upside down in each pan.
2. Place one brick on top of one of the ice blocks. Place two bricks on top of another ice block. Do not put any bricks on the third ice block.
3. After 15 min, remove the bricks from the ice blocks.
4. Using the graduated cylinder, measure the amount of water that has melted from each ice block.
5. Observe and record your findings.

Analyze the Results

1. **Analyzing Data** Which ice block produced the most water?
2. **Explaining Events** What did the bricks represent?
3. **Analyzing Results** What part of the ice blocks melted first? Explain.

Draw Conclusions

4. **Interpreting Information** How could you relate this investigation to the melting rate of glaciers? Explain.

Applying Your Data

Replace the clay with different materials, such as soft wood or sand. How does each ice block affect the different surface materials? What types of surfaces do the different materials represent?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Chapter Review

USING KEY TERMS

For each pair of terms, explain how the meanings of the terms differ.

1 *shoreline* and *longshore current*

2 *beaches* and *dunes*

3 *deflation* and *saltation*

4 *continental glacier* and *alpine glacier*

5 *stratified drift* and *till*

6 *mudflow* and *creep*

UNDERSTANDING KEY IDEAS

Multiple Choice

7 *Surf* refers to

a. large storm waves in the open ocean.
b. giant waves produced by hurricanes.
c. breaking waves near the shoreline.
d. small waves on a calm sea.

8 When waves cut completely through a headland, a ___ is formed.

a. sea cave
b. sea arch
c. wave-cut terrace
d. sandbar

9 A narrow strip of sand that is formed by wave deposition and is connected to the shore is called a

a. barrier spit.
b. sandbar.
c. wave-cut terrace.
d. headland.

10 A wind-eroded depression is called a

a. deflation hollow.
b. desert pavement.
c. dune.
d. dust bowl.

11 What term describes all types of glacial deposits?

a. glacial drift
b. dune
c. till
d. outwash

12 Which of the following is NOT a landform created by an alpine glacier?

a. cirque
b. deflation hollow
c. horn
d. arête

13 What is the term for a mass movement that is of volcanic origin?

a. lahar
b. slump
c. creep
d. rock fall

14 Which of the following is a slow mass movement?

a. mudflow
b. landslide
c. creep
d. rock fall

Short Answer

15 Why do waves break when they near the shore?

16 Why are some areas more affected by wind erosion than other areas are?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

17 What kind of mass movement happens continuously, day after day?

18 In what direction do sand dunes move?

19 Describe the different types of glacial moraines.

CRITICAL THINKING

20 **Concept Mapping** Use the following terms to create a concept map: *deflation, strong winds, saltation, dune,* and *desert pavement.*

21 **Making Inferences** How do humans increase the likelihood that wind erosion will occur?

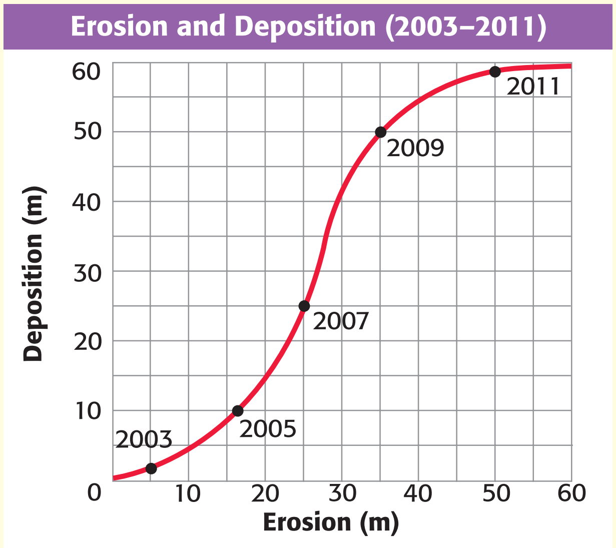
22 **Identifying Relationships** If the large ice sheet covering Antarctica were to melt completely, what type of landscape would you expect Antarctica to have?

23 **Applying Concepts** You are a geologist who is studying rock to determine the direction of flow of an ancient glacier. What clues might help you determine the glacier's direction of flow?

24 **Applying Concepts** You are interested in purchasing a home that overlooks the ocean. The home that you want to buy sits atop a steep sea cliff. Given what you have learned about shoreline erosion, what factors would you take into consideration when deciding whether to buy the home?

INTERPRETING GRAPHICS

The graph below illustrates coastal erosion and deposition at an imaginary beach over a period of 8 years. Use the graph below to answer the questions that follow.

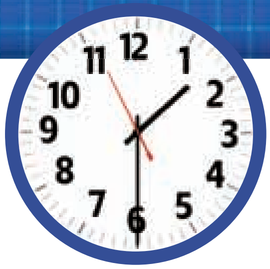


25 What is happening to the beach over time?

26 In what year does the amount of erosion equal the amount of deposition?

27 Based on the erosion and deposition data for 2005, what might happen to the beach in the years that follow 2005?

Copyright © by Holt, Rinehart and Winston. All rights reserved.



Standardized Test Preparation

READING

Read each of the passages below. Then, answer the questions that follow each passage.

Passage 1 When you drop a pebble into a pond, is there just one ripple? Of course not. Waves, like ripples, don't move alone. Waves travel in groups called wave trains. As wave trains move away from their sources, they travel through the ocean water uninterrupted. But when waves reach shallow water, they change form because the ocean floor crowds the lower part of the wave. As a result, the waves get closer together and taller.

1. In this passage, what does the word *uninterrupted* mean?

- **A** not continuous
- **B** not broken
- **C** broken again
- **D** not interpreted

2. In this passage, what does the word *train* mean?

- **F** to teach someone a skill
- **G** the part of a gown that trails behind the person who is wearing the gown
- **H** a series of moving things
- **I** a series of railroad cars

3. According to the passage, what is the cause of taller waves?

- **A** shallow water
- **B** deep ocean water
- **C** rippling
- **D** wave trains

4. If certain waves are short and far apart, which of the following can be concluded?

- **F** The waves are approaching the shore.
- **G** The waves are moving toward their source.
- **H** The waves were interrupted.
- **I** The waves are in deep ocean water.

Passage 2 Winter storms create powerful waves that crash into cliffs and break off pieces of rock that fall into the ocean. On February 8, 1998, unusually large waves crashed against the cliffs along Broad Beach Road in Malibu, California. Eventually, the ocean-eroded cliffs buckled, which caused a landslide. One house collapsed into the ocean, and two more houses dangled on the edge of the cliff's newly eroded face. Powerful waves, buckled cliffs, and landslides are part of the ongoing natural process of coastal erosion that is taking place along the California shoreline and along similar shorelines throughout the world.

1. In this passage, what does *buckled* mean?

- **A** tightened
- **B** collapsed
- **C** formed
- **D** heated up

2. Which of the following describes how this coastal area was damaged?

- **F** The area was damaged by collapsing houses.
- **G** The area was damaged an earthquake.
- **H** The area was damaged by ocean currents.
- **I** The area was damaged by unusually large waves produced by a winter storm.

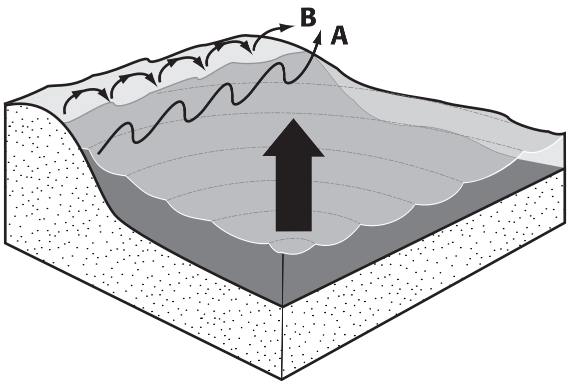
3. Which of the following can be concluded from this passage?

- **A** This area may have landslides in the future.
- **B** This area is safe from future landslides.
- **C** This type of landslide is common only to the California coastline.
- **D** Erosion in this area happens very rarely.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

INTERPRETING GRAPHICS

Use each figure below to answer the questions that follow each figure.

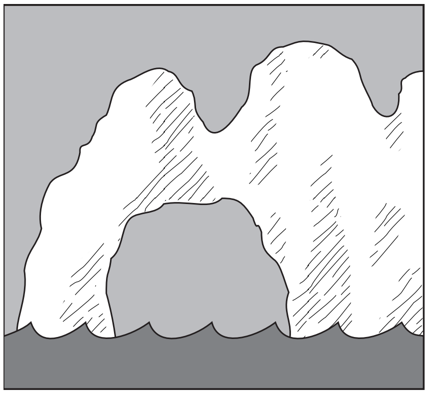


1. In the illustration, what does A label?

A wave direction
B wave amplitude
C wavelength
D a longshore current

2. In the illustration, what does B label?

F wave direction
G wave period
H the movement of sand
I a longshore current



3. What process created the landform in the illustration above?

A erosion by waves
B saltation
C abrasion
D deposition by waves

MATH

Read each question below, and choose the best answer.

1. Wind erosion caused a deflation hollow that was circular in shape. The hollow is 100 m wide. What is the circumference of this deflation hollow?

A 31.4 m
B 62.8 m
C 314 m
D 628 m

2. A homeowner needs to buy and plant 28 trees to prevent wind erosion. Each tree costs \$29.99. What is a reasonable estimate for the total cost of these trees before tax?

F a little more than \$200
G a little less than \$600
H a little less than \$900
I a little more than \$1,000

Use the equation below to answer the questions that follow.

$$\textit{number of waves per minute} = \frac{60 \text{ s}}{\textit{wave period} \text{ (s)}}$$

3. If the wave period is 15 s, how many waves occur in 1 min?

A 4
B 60
C 75
D 240

4. If the wave period is 30 s, how many waves occur in 1 min?

F 1
G 2
H 3
I 5

5. If 480 waves broke in 40 min, what is the wave period?

A 5 s
B 12 s
C 15 s
D 20 s

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Science in Action

Weird Science

Long-Runout Landslides

At 4:10 A.M. on April 29, 1903, the town of Frank, Canada, was changed forever when disaster struck without warning. An enormous chunk of limestone fell suddenly from the top of nearby Turtle Mountain. In less than two minutes, the huge mass of rock buried most of the town! Landslides such as the Frank landslide are now known as *long-runout landslides*. Most landslides travel a horizontal distance that is less than twice the vertical distance that they have fallen. But long-runout landslides carry enormous amounts of rock and thus can travel many times farther than they fall. The physics of long-runout landslides are still a mystery to scientists.

Math Activity

The Frank landslide traveled 4 km in 100 s. Calculate this speed in meters per second.

Scientific Discoveries

The Lost Squadron

During World War II, an American squadron of eight planes crash-landed on the ice of Greenland. The crew was rescued, but the planes were lost. After the war, several people tried to find the "Lost Squadron." Finally, in 1988, a team of adventurers found the planes by using radar. The planes were buried by 40 years of snowfall and had become part of the Greenland ice sheet! When the planes were found, they were buried under 80 m of glacial ice. Incredibly, the team tunneled down through the ice and recovered a plane. The plane is now named Glacier Girl, and it still flies today!

Language Arts Activity

WRITING SKILL The crew of the Lost Squadron had to wait 10 days to be rescued by dog sled. Imagine that you were part of the crew—what would you have done to survive? Write a short story describing your adventure on the ice sheet of Greenland.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Careers

Johan Reinhard

High-Altitude Anthropologist Imagine discovering the mummified body of a girl from 500 years ago! In 1995, while climbing Mount Ampato, one of the tallest mountains in the Andes, Johan Reinhard made an incredible discovery—the well-preserved mummy of a young Inca girl. The recent eruption of a nearby volcano had caused the snow on Mount Ampato to melt and uncover the mummy. The discovery of the "Inca Ice Maiden" gave scientists a wealth of new information about Incan culture. Today, Reinhard considers the discovery of the Inca Ice Maiden his most exciting moment in the field.

Johan Reinhard is an anthropologist. Anthropologists study the physical and cultural characteristics of human populations. Reinhard studied anthropology at the University of Arizona and at the University of Vienna, in Austria. Early in his career, Reinhard worked on underwater archeology projects in Austria and Italy and on projects in the mountains of Nepal and Tibet. He soon made mountains and mountain peoples the focus of his career as an anthropologist. Reinhard spent 10 years in the highest mountains on Earth, the Himalayas. There, he studied the role of sacred mountains in Tibetan religions. Now, Reinhard studies the culture of the ancient Inca in the Andes of South America.

Social Studies ACTIVITY

Find out more about the Inca Ice Maiden or about Ötzi, a mummy that is more than 5,000 years old that was found in a glacier in Italy. Create a poster that summarizes what scientists have learned from these discoveries.

The Inca Ice Maiden was buried under ice and snow for more than 500 years.

To learn more about these Science in Action topics, visit **go.hrw.com** and type in the keyword **HZ5ICEF.**

Current Science

Check out Current Science® articles related to this chapter by visiting go.hrw.com. Just type in the keyword HZ5CS12.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

UNIT 3

TIMELINE

Our Solar System

In this unit, you will learn about the science of astronomy. Long before science was called science, people looked up at the night sky and tried to understand the meaning of the twinkling lights above. Early astronomers charted the stars and built calendars based on the movement of the sun, moon, and planets. Today, scientists from around the world have come together to place a space station in orbit around the Earth. This timeline shows some of the events that have occurred throughout human history as scientists have come to understand more about our planet's "neighborhood" in space.

1054

Chinese and Korean astronomers record the appearance of a supernova, an exploding star. Strangely, no European observations of this event have ever been found.

The Crab Nebula

Andromeda Nebula

1924

An astronomer named Edwin Hubble confirms the existence of other galaxies.

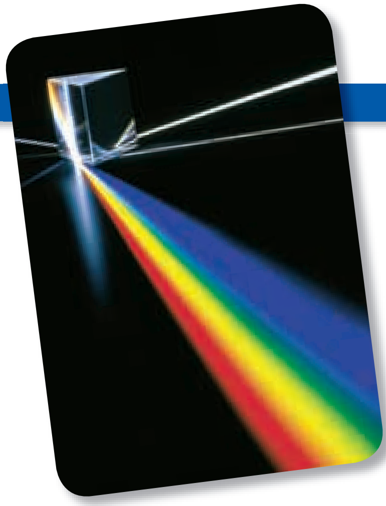
1983

Sally Ride becomes the first American woman to travel in space.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

1582

Ten days are dropped from October as the Julian calendar is replaced by the Gregorian calendar.



1666

Using a prism, Isaac Newton discovers that white light is composed of different colors.

1898

The War of the Worlds, by H. G. Wells, is published.

1958

The National Aeronautics and Space Administration (NASA) is established to oversee the exploration of space.

1970

Apollo 13 is damaged shortly after leaving orbit. The spacecraft's three astronauts navigate around the moon to return safely to the Earth.

1977

Voyager 1 and *Voyager 2* are launched on missions to Jupiter, Saturn, and beyond. Now more than 10 billion kilometers away from the Earth, they are still sending back information about space.

Voyager 2

1992

Astronomers discover the first planet outside the solar system.

1998

John Glenn becomes the oldest human in space. His second trip into space comes 36 years after he became the first American to orbit the Earth.

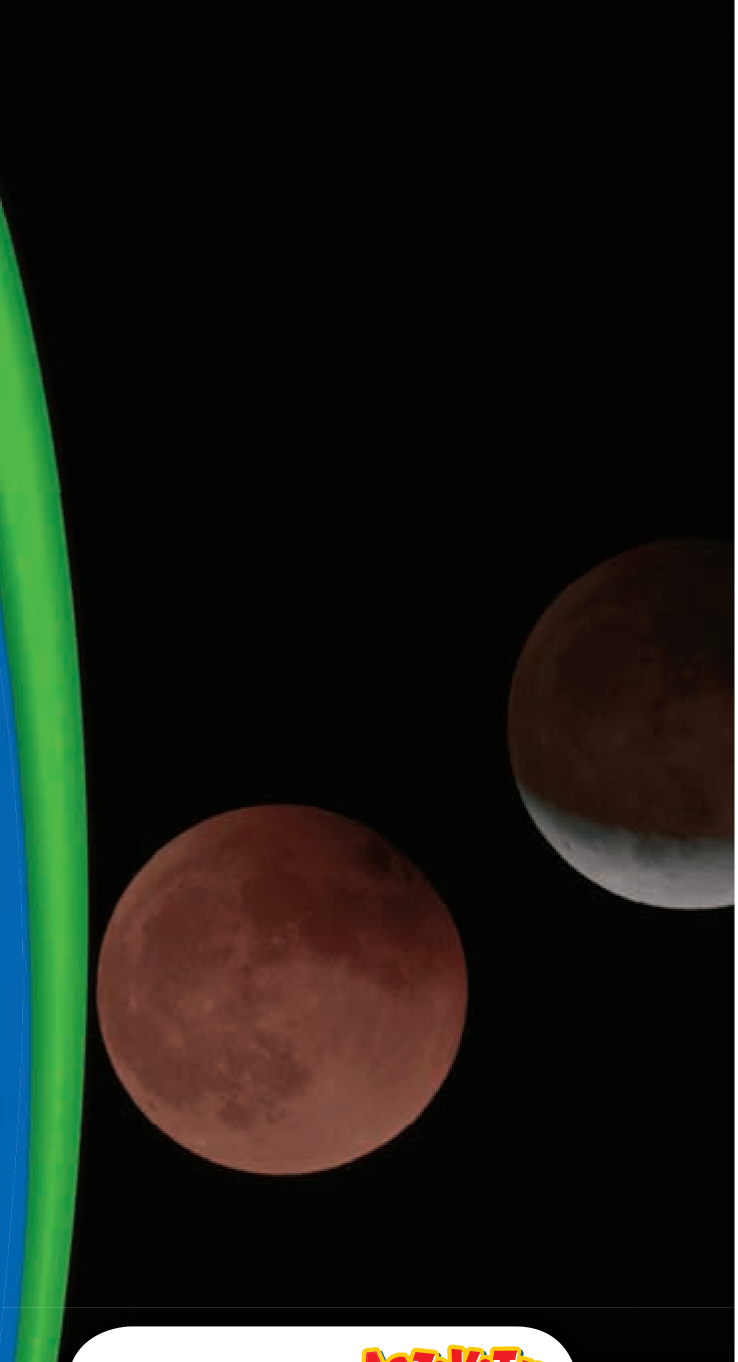
2003

Astronomers discover three distant quasars that date back to a time when the universe was only 800 million years old. It takes light 13 billion years to reach Earth from the farthest of the three quasars.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

9

Earth, Sun, and Moon

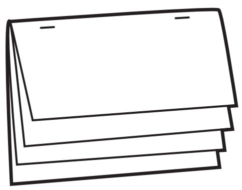


About the PHOTO

The lunar eclipse shown in this time-lapse photo was seen by people all over the world. A lunar eclipse happens when the Earth comes between the sun and the moon and the shadow of the Earth falls on the moon. Earth's atmosphere causes the moon to be cast in a red light. In this chapter, you will learn about how the changing positions of the Earth, the sun, and the moon cause eclipses as well as the seasons and the tides.

PRE-READING ACTIVITY

FOLDNOTES **Layered Book** Before you read the chapter, create the FoldNote entitled "Layered Book" described in the **Study Skills** section of the Appendix. Label the tabs of the layered book with "Planetary Motion," "Days and Seasons," "Lunar Cycles," and "Tides." As you read the chapter, write information you learn about each category under the appropriate tab.



Copyright © by Holt, Rinehart and Winston. All rights reserved.

START-UP ACTIVITY

How Long Is Your Day?

In this activity, you will show how Earth's tilt and revolution around the sun cause changes in day length.

Procedure

1. Set a **globe** on a **table.** Turn off the lights.
2. Have your partner point the beam of a **flashlight** toward the globe's equator, with the globe's North Pole tilted away from the flashlight. Hold the flashlight in the same position at all times.
3. Turn the globe so that North Carolina faces the flashlight.
4. Use a **piece of string** to measure the width of the lighted part of the globe along the line of latitude nearest your hometown.
5. Record this distance by placing a piece of **tape** at the ends of the string where they meet the edge of light and darkness.
6. Turn the base of the globe 90°. Repeat steps 3–5 along the same line of latitude.
7. Turn the base of the globe 90°. The North Pole should be facing toward the flashlight. Repeat steps 3–5.

Analysis

1. Lay the three pieces of string side by side on the table. What does the difference in length of the strings indicate?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 1

Planetary Motion

Why do Earth and the other planets revolve around the sun? Why don't they fly off into space? Does something hold them in their paths?

READING WARM-UP

Objectives

- Explain the difference between rotation and revolution.
- Describe three laws of planetary motion.
- Describe how distance and mass affect gravitational attraction.

Terms to Learn

rotation
orbit
revolution

READING STRATEGY

Paired Summarizing Read this section silently. In pairs, take turns summarizing the material. Stop to discuss ideas that seem confusing.

rotation the spin of a body on its axis

orbit the path that a body follows as it travels around another body in space

revolution the motion of a body that travels around another body in space; one complete trip along an orbit

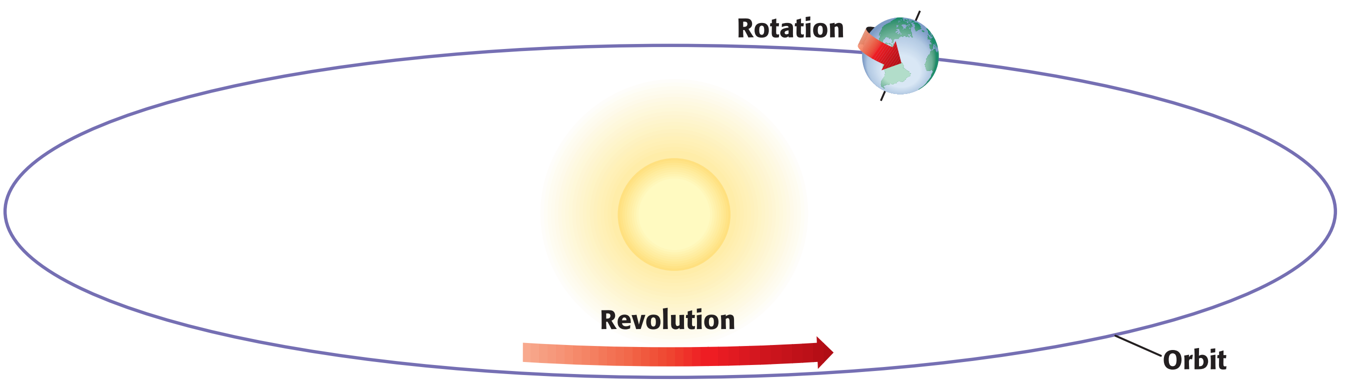
To answer these questions, you need to go back in time to look at the discoveries made by the scientists of the 1500s and 1600s. Danish astronomer Tycho Brahe (TIE koh BRAH uh) carefully observed the positions of planets for more than 25 years. When Brahe died in 1601, a German astronomer named Johannes Kepler (yoh HAHN uhs KEP luhr) continued Brahe's work. Kepler set out to understand the motions of planets and to describe the solar system.

A Revolution in Astronomy

Each planet spins on its axis. The spinning of a body, such as a planet, on its axis is called **rotation.** As the Earth rotates, only one-half of the Earth faces the sun. The half that faces the sun is light and is experiencing daytime. The half that faces away from the sun is dark and is experiencing nighttime.

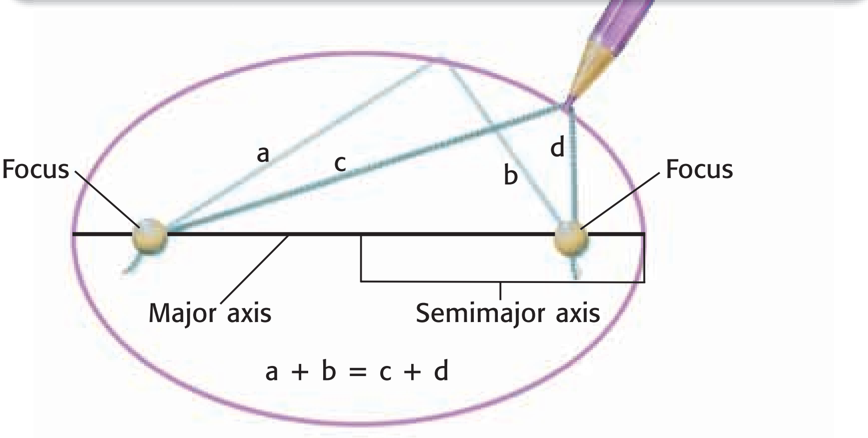
The path that a body follows as it travels around another body in space is called the **orbit.** One complete trip along an orbit is called a **revolution.** The amount of time a planet takes to complete a single trip around the sun is called a *period of revolution*. Each planet takes a different amount of time to circle the sun. Earth's period of revolution is about 365.25 days (a year), but Mercury orbits the sun in only 88 days. **Figure 1** illustrates the orbit and revolution of the Earth around the sun as well as the rotation of the Earth on its axis.

Figure 1 *A planet rotates on its own axis and revolves around the sun in a path called an* orbit.



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 2 **Parts of an Ellipse**



Kepler's First Law of Motion

Kepler's first discovery came from his careful study of Mars. Kepler discovered that Mars did not move in a circle around the sun but moved in an elongated circle called an *ellipse*. This finding became Kepler's first law of motion. An ellipse is a closed curve in which the sum of the distances from the edge of the curve to two points inside the ellipse is always the same, as shown in **Figure 2.** An ellipse's maximum length is called its *major axis*. Half of this distance is the *semimajor axis,* which is usually used to describe the size of an ellipse. The semimajor axis of Earth's orbit—the maximum distance between Earth and the sun—is about 150 million kilometers.

Kepler's Second Law of Motion

Kepler's second discovery, or second law of motion, was that the planets seemed to move faster when they are close to the sun and slower when they are farther away. To understand this idea, imagine that a planet is attached to the sun by a string, as modeled in **Figure 3.** When the string is shorter, the planet must move faster to cover the same area.

Kepler's Third Law of Motion

Kepler noticed that planets that are more distant from the sun, such as Saturn, take longer to orbit the sun. This finding was Kepler's third law of motion, which explains the relationship between the period of a planet's revolution and its semimajor axis. Knowing how long a planet takes to orbit the sun, Kepler was able to calculate the planet's distance from the sun.

Reading Check **Describe Kepler's third law of motion.** (*See the Appendix for answers to Reading Checks.*)

MATH PRACTICE

Kepler's Formula

Kepler's third law can be expressed with the formula

$$P^2 = a^3$$

where P is the period of revolution and a is the semimajor axis of an orbiting body. For example, Mars's period is 1.88 years, and its semimajor axis is 1.523 AU. Thus, $1.88^2 = 1.523^3 = 3.53$. Calculate a planet's period of revolution if the semimajor axis is 5.74 AU.

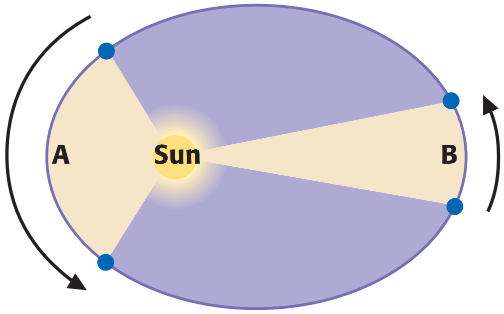


Figure 3 *According to Kepler's second law, to keep the area of* A *equal to the area of* B*, the planet must move faster in its orbit when it is closer to the sun.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Quick Lab

Staying in Focus

1. Take a **short piece of string,** and pin both ends to a **piece of paper** by using **two thumbtacks.**
2. Keeping the string stretched tight at all times, use a **pencil** to trace the path of an ellipse.
3. Change the distance between the thumbtacks to change the shape of the ellipse.
4. How does the position of the thumbtacks (foci) affect the ellipse?

Newton to the Rescue!

Kepler wondered what caused the planets closest to the sun to move faster than the planets farther away. However, he never found an answer. Sir Isaac Newton finally put the puzzle together when he described the force of gravity. Newton didn't understand why gravity worked or what caused it. Even today, scientists do not fully understand gravity. But Newton combined the work of earlier scientists and used mathematics to explain the effects of gravity.

The Law of Universal Gravitation

Newton reasoned that an object falls toward Earth because Earth and the object are attracted to each other by gravity. He discovered that this attraction depends on the masses of the objects and the distance between the objects.

Newton's *law of universal gravitation* states that the force of gravity depends on the product of the masses of the objects divided by the square of the distance between the objects. The larger the masses of two objects and the closer together the objects are, the greater the force of gravity between the objects. For example, if the distance between two objects doubles, the gravitational attraction between them will decrease by 2×2 (a factor of 4), as shown in **Figure 4.** If the distance between two objects increases by a factor of 10, the gravitational attraction between them will decrease by 10×10 (a factor of 100).

Both Earth and the moon are attracted to each other. Although it may seem as if Earth does not orbit the moon, Earth and the moon actually orbit each other.

Reading Check **Explain Newton's law of universal gravitation.**

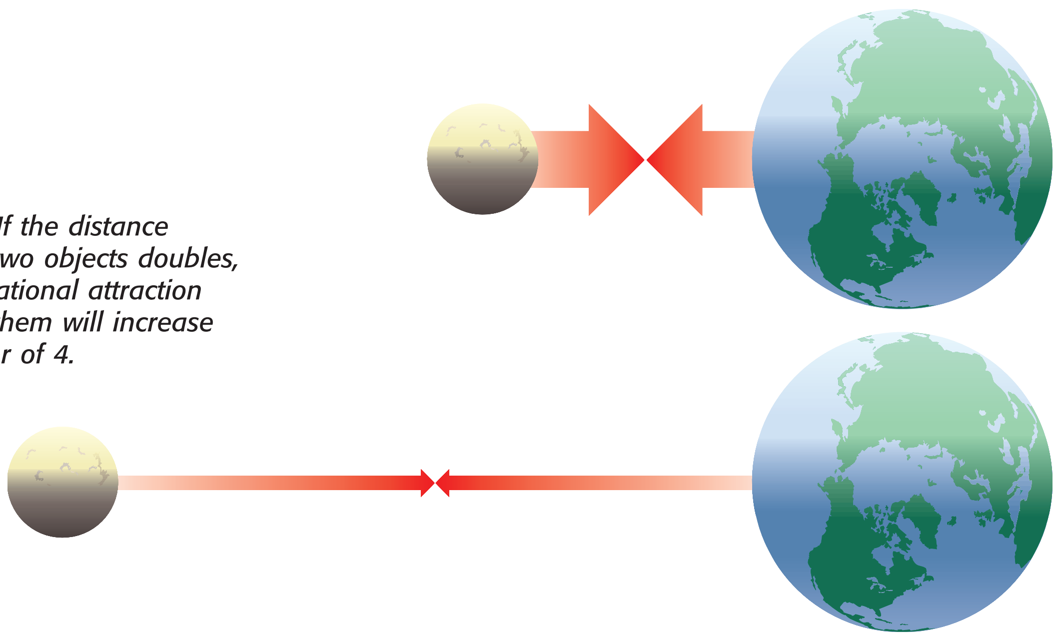


Figure 4 *If the distance between two objects doubles, the gravitational attraction between them will increase by a factor of 4.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Orbits Falling Down and Around

If you drop a rock, it falls to the ground. So, why doesn't the moon come crashing into the Earth? The answer has to do with the moon's inertia. *Inertia* is an object's resistance in speed or direction until an outside force acts on the object. In space, there isn't any air to cause resistance and slow down the moving moon. Therefore, the moon continues to move, but gravity keeps the moon in orbit, as **Figure 5** shows.

Imagine twirling a ball on the end of a string. As long as you hold the string, the ball will orbit your hand. As soon as you let go of the string, the ball will fly off in a straight path. This same principle applies to the moon. Gravity keeps the moon from flying off in a straight path. This principle holds true for all bodies in orbit, including the Earth and other planets in our solar system.

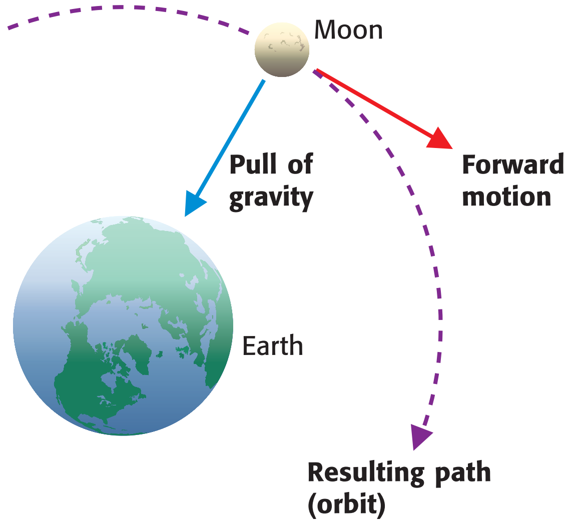


Figure 5 *Gravity causes the moon to fall toward the Earth and changes a straight-line path into a curved orbit.*

SECTION Review

Summary

- Rotation is the spinning of a planet on its axis, and revolution is one complete trip along an orbit.
- Planets move in an ellipse around the sun. The closer they are to the sun, the faster they move. The period of a planet's revolution depends on the planet's semimajor axis.
- Gravitational attraction decreases as distance increases and as mass decreases.

Using Key Terms

1. In your own words, write a definition for each of the following terms: *revolution* and *rotation*.

Understanding Key Ideas

2. Kepler discovered that planets move faster when they
   a. are farther from the sun.
   b. are closer to the sun.
   c. have more mass.
   d. rotate faster.
3. On what properties does the force of gravity between two objects depend?
4. How does gravity keep a planet moving in an orbit around the sun?

Math Skills

5. The Earth's period of revolution is 365.25 days. Convert this period of revolution into hours.

Critical Thinking

6. **Applying Concepts** If a planet had two moons and one moon was twice as far from the planet as the other, which moon would complete a revolution of the planet first? Explain your answer.
7. **Making Comparisons** Describe the three laws of planetary motion. How is each law related to the other laws?

SCILINKS® NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Kepler's Laws
SciLinks code: HSM0216

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 2

Days and Seasons on Earth

Have you ever noticed that a winter day has fewer hours of daylight compared with a summer day? During the winter, it may get dark as early as 6:00 p.m. However, in the summer, it may not get dark until 9:00 p.m. What causes these differences?

The answer to this question has to do with the motion of the Earth as it revolves around the sun. Learning more about how the Earth moves will also help you understand why we have daylight and night—even the seasons of the year.

READING WARM-UP

Objectives

- Explain the cause of daylight and night.
- Explain how the tilt and movement of the Earth cause changes in seasons and the length of a day.
- Describe what causes equinoxes and solstices.
- Describe how latitude affects the amount of seasonal change that an area experiences.

Terms to Learn

day
equinox
solstice

READING STRATEGY

Reading Organizer As you read this section, create an outline of the section. Use the headings from the section in your outline.

The Earth-Sun System

You now know that the Earth revolves around the sun in an ellipse, or elongated circle. It takes 1 year, or $365\frac{1}{4}$ days, for the Earth to revolve once around the sun. But it's the Earth's rotation that is a direct cause of daylight and night.

Earth's Rotation

It takes the Earth 23 hours and 56 minutes to rotate once on its axis. The Earth's axis is an imaginary line that runs through the center of the Earth from the North Pole to the South Pole. **Figure 1** shows the Earth's rotation on its axis and revolution around the sun.

We usually think of a day as the hours of light we experience. But a **day** is also the time required for the Earth to rotate once on its axis. A day includes the time of light and dark. The Earth's rotation causes daylight and night. Because the Earth rotates counterclockwise as seen from above the North Pole, the sun appears to rise in the east and set in the west.

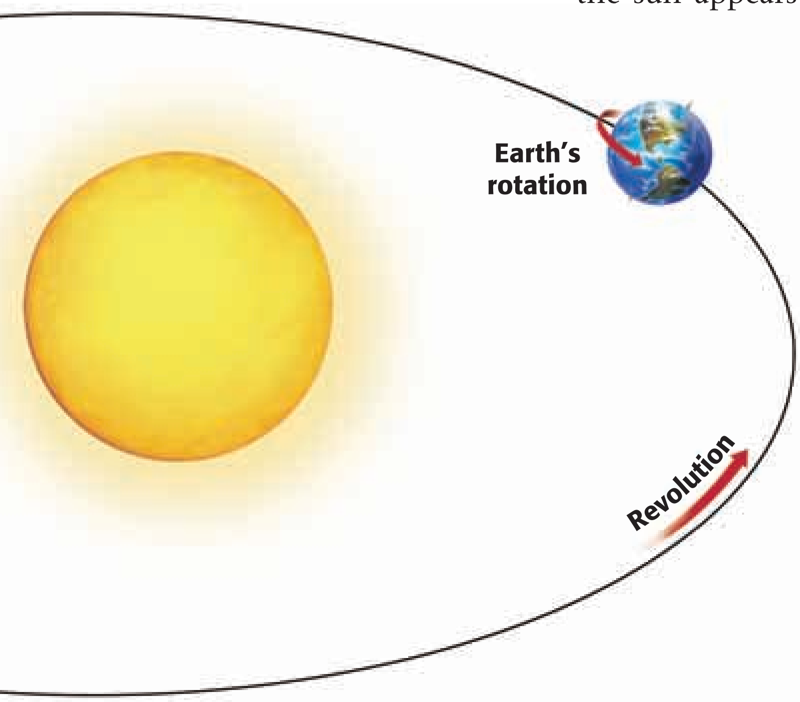
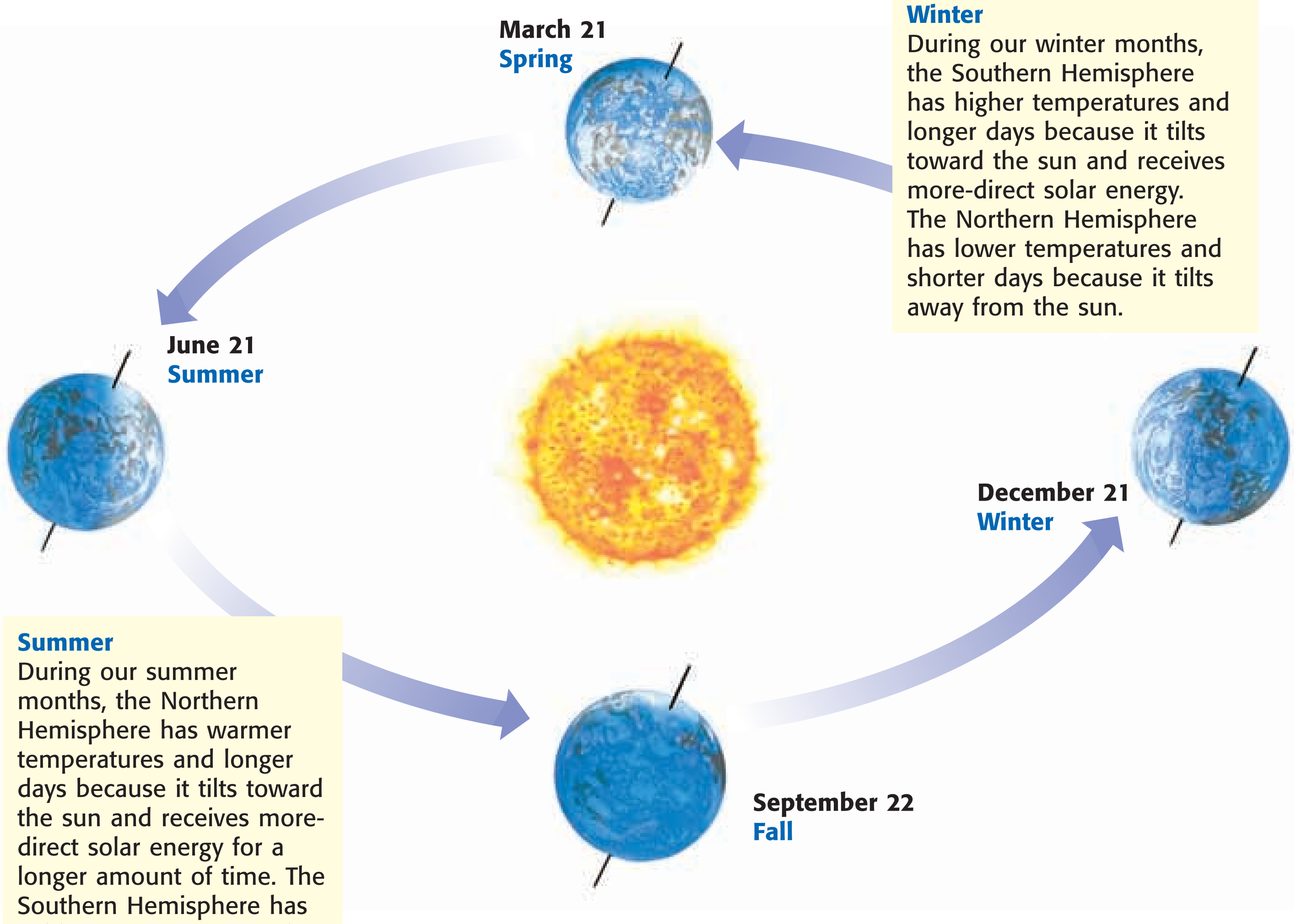


Figure 1 *The side of Earth that faces the sun gets light, which is daytime. The side of Earth that faces away from the sun is dark, which is nighttime.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 2 **The Seasons**



Winter
During our winter months, the Southern Hemisphere has higher temperatures and longer days because it tilts toward the sun and receives more-direct solar energy. The Northern Hemisphere has lower temperatures and shorter days because it tilts away from the sun.

Summer
During our summer months, the Northern Hemisphere has warmer temperatures and longer days because it tilts toward the sun and receives more-direct solar energy for a longer amount of time. The Southern Hemisphere has colder temperatures and shorter days because it tilts away from the sun.

Earth's Tilt

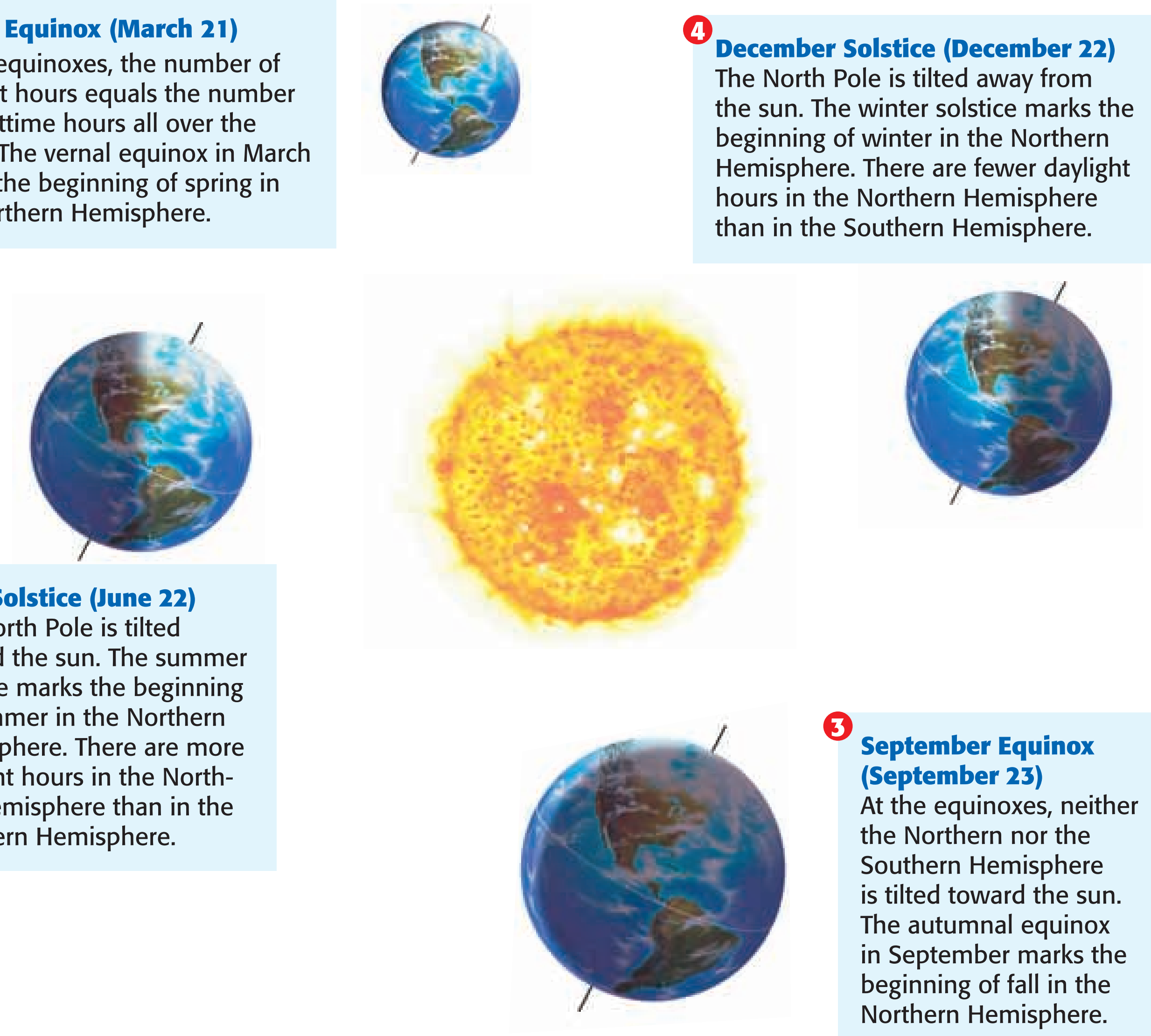
The seasons are caused mainly by the 23.5° tilt of the Earth's axis. This tilt causes the number of daylight hours to change depending on the time of year. During the winter, there are fewer daylight hours in the Northern Hemisphere. This is because the Northern Hemisphere is tilted away from the sun. During the summer there are more daylight hours in the Northern Hemisphere. This is because the Northern Hemisphere is tilted toward the sun. **Figure 2** shows how the tilt of the Earth affects the amount of sunlight an area will receive.

day the time required for Earth to rotate once on its axis

Reading Check **What causes the seasons?** *(See the Appendix for answers to Reading Checks.)*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 3 **The Seasons' Yearly Cycle**



1 March Equinox (March 21)
At the equinoxes, the number of daylight hours equals the number of nighttime hours all over the world. The vernal equinox in March marks the beginning of spring in the Northern Hemisphere.

2 June Solstice (June 22)
The North Pole is tilted toward the sun. The summer solstice marks the beginning of summer in the Northern Hemisphere. There are more daylight hours in the Northern Hemisphere than in the Southern Hemisphere.

3 September Equinox (September 23)
At the equinoxes, neither the Northern nor the Southern Hemisphere is tilted toward the sun. The autumnal equinox in September marks the beginning of fall in the Northern Hemisphere.

4 December Solstice (December 22)
The North Pole is tilted away from the sun. The winter solstice marks the beginning of winter in the Northern Hemisphere. There are fewer daylight hours in the Northern Hemisphere than in the Southern Hemisphere.

The Seasons' Yearly Cycle

The Earth's tilt and shape affect the amount of sunlight an area will receive. But what does the Earth-sun system look like at different times of the year? The seasons' yearly cycle is caused by the Earth's tilt and revolution around the sun.

equinox the moment when the sun's path passes the celestial equator

solstice the point at which the sun is as far north or as far south of the equator as possible

Equinoxes

In **Figure 3** you can see that in March and September, neither end of the Earth's axis is tilted toward the sun. Both hemispheres receive the same amount of solar energy. This is because the sun is directly above the equator. The time when the sun is directly above the equator is called **equinox** (EE kwi nahks).

Reading Check **What is an equinox?**

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Solstices

A **solstice** is the time when the sun is farthest north or south of the equator. In June, the Northern Hemisphere is tilted toward the sun, so it is warmer there than it is at the Southern Hemisphere. At this time, the Northern Hemisphere receives more daylight hours than the Southern Hemisphere. In December, the opposite happens because the Southern Hemisphere is tilted toward the sun.

Latitude

Some places on Earth do not have much seasonal change. This is because sunlight hits the Earth's surface differently depending on latitude. Near the equator both the temperature and the amount of daylight stay about the same year-round. At the North and South Poles, the same amount of sunlight is spread over a larger area. This happens because the Earth is curved, as seen in **Figure 4**.

Figure 4 *The sun's energy is spread over a greater area at the poles than at the equator.*

SECTION Review

Summary

- Daylight and night are caused by the rotation of Earth on its axis.
- The seasons and the number of daylight hours are caused by the tilt of Earth's axis.
- Equinoxes and solstices are caused by Earth's tilt and it's revolution around the sun.
- The amount of seasonal change a region receives is determined by the latitude of the region.

Using Key Terms

The statements below are false. For each statement, replace the underlined term to make a true statement.

1. A <u>day</u> is the time at which the sun is farthest north or south of the equator.
2. An <u>equinox</u> is the time it takes the Earth to rotate once on its axis.

Understanding Key Ideas

3. The time at which the North Pole is tilted toward the sun and the Northern Hemisphere receives more daylight hours than the Southern Hemisphere is called
   a. the March Equinox.
   b. the June Solstice.
   c. The September Equinox.
   d. The December Solstice.
4. What causes daylight and night on Earth?

Math Skills

5. Sunlight travels through space to the Earth at a speed of 300,000 km/s. The average distance between the sun and the Earth is 150 million kilometers. How long does light take to travel from the sun to Earth?

Critical Thinking

6. **Applying Concepts** If the Earth were not tilted, would we have seasons?

SCILINKS® NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Latitude and Longitude
SciLinks code: HSTE035

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 3

Lunar Cycles

Have you ever wondered why the moon looks different throughout the month? Sometimes it's a big glowing ball, but other times it's just a sliver.

READING WARM-UP

Objectives

- Explain how the Earth's movement and the moon's orbit cause the phases of the moon.
- Explain the difference between a solar eclipse and a lunar eclipse.

Terms to Learn

phase
eclipse

READING STRATEGY

Prediction Guide Before reading this section, write the title of each heading in this section. Next, under each heading, write what you think you will learn.

Since the earliest times, people have looked at the sky to learn more about the moon. They wondered about the changing appearance of the moon and noticed the same changes happening month after month. When you look up at the moon, you see what ancient people saw. These changes in the moon's appearance are called the *phases of the moon*. Read on to find out about the phases of the moon.

The Earth-Moon System

You now know that the Earth rotates on its axis and revolves around the sun. But did you know that the moon rotates on its axis as it moves around the Earth? Take a look at **Figure 1.** Every 27.3 days the moon revolves once around the Earth and rotates once on its axis. The moon rotates on its axis and revolves around the Earth at the same rate. For this reason, we always see the same side of the moon.

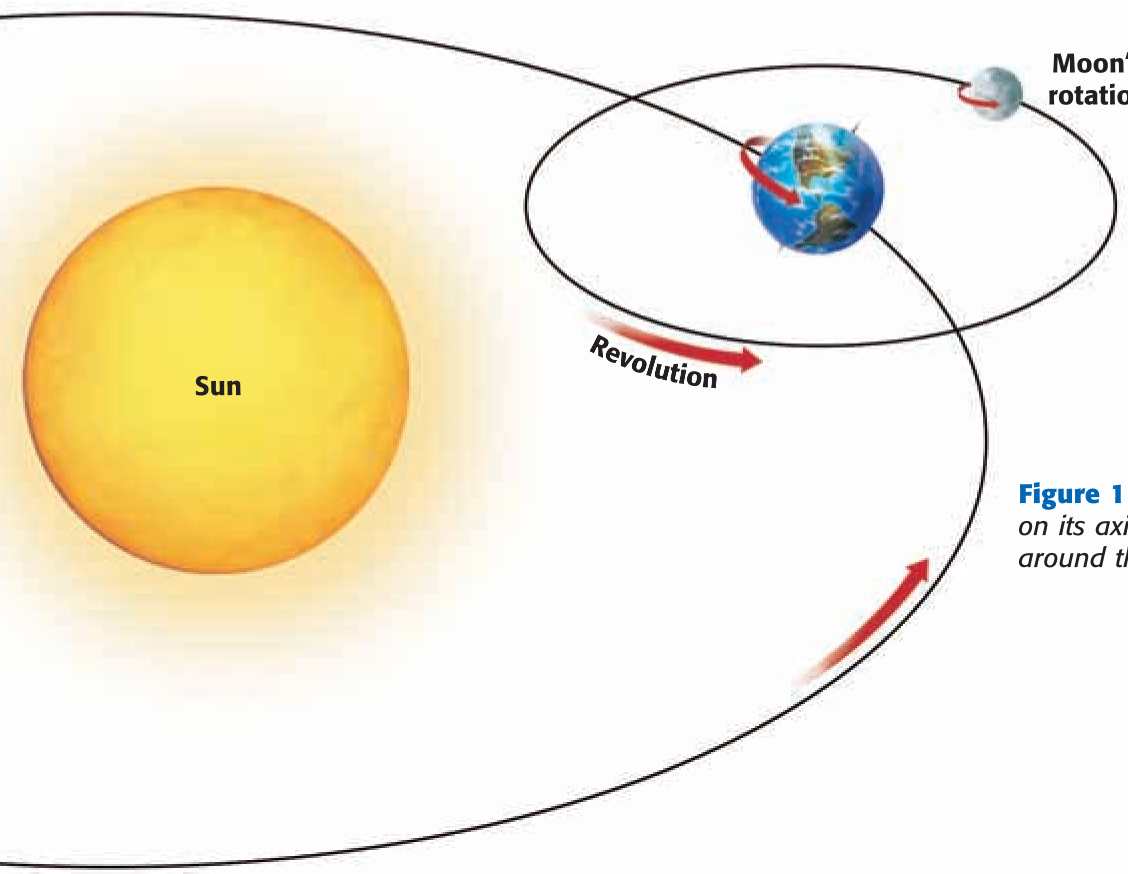
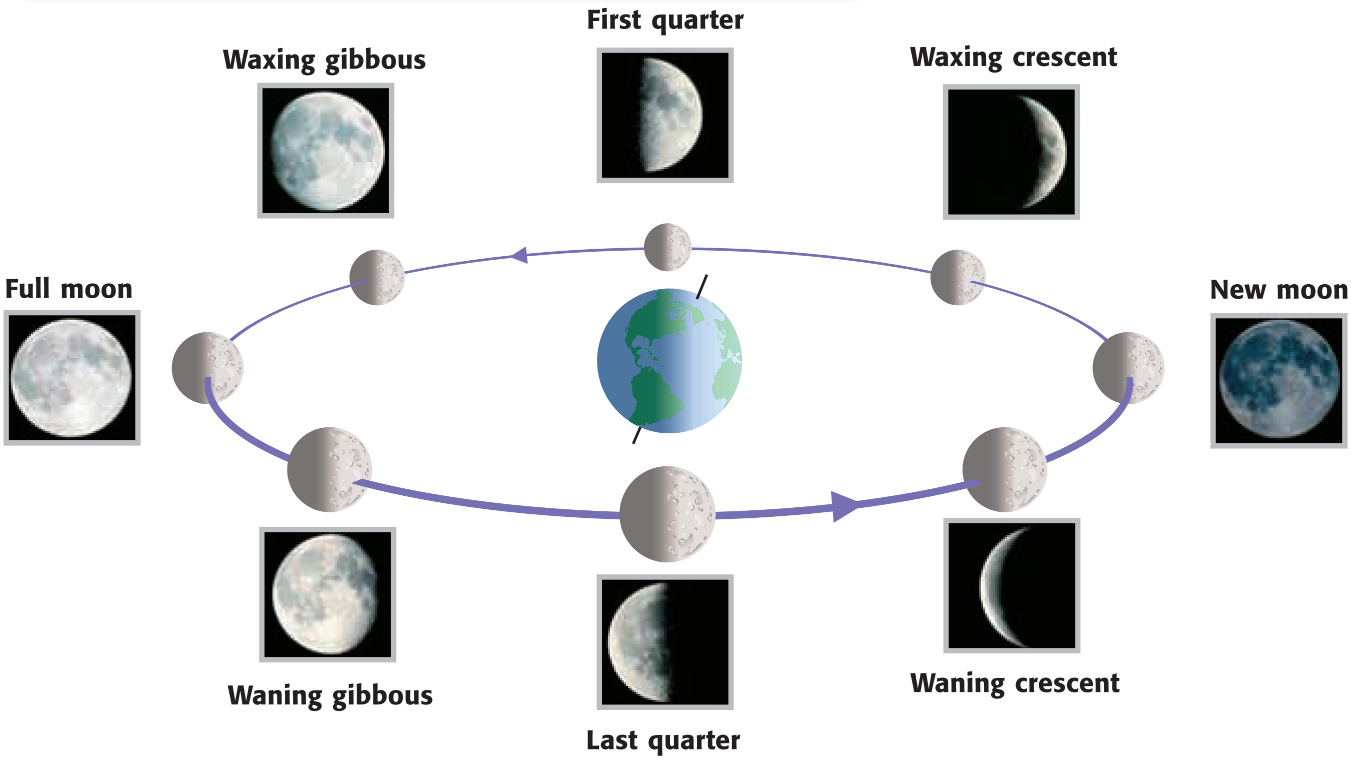


Figure 1 *The moon rotates on its axis and revolves around the Earth.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 2 **The Phases of the Moon**



Phases of the Moon

From Earth, one of the most noticeable aspects of the moon is its continually changing appearance. Within a month, its Earthward face changes from a fully lit circle to a thin crescent and then back to a circle. These different appearances of the moon result from its changing position with respect to the Earth and the sun. As the moon revolves around the Earth, the amount of sunlight that the moon reflects off the side of the moon that faces the Earth changes. The different appearances of the moon due to its changing position are called **phases.** The phases of the moon are shown in **Figure 2.**

phase the change in the sunlit area of one celestial body as seen from another celestial body

Waxing and Waning

When the moon is *waxing*, the sunlit part we can see from Earth appears to get larger. When the moon is *waning*, the sunlit part seen from Earth appears to get smaller. Notice that even as the phases of the moon change, the total amount of sunlight that the moon receives remains the same. Half the moon is always in sunlight, just as half the Earth is always in sunlight. But because the rate of rotation for the moon is the same as its period of revolution, on Earth we always see the same side of the moon.

Reading Check **What is the difference between waxing and waning?** (*See the Appendix for answers to Reading Checks.*)

MATH PRACTICE

Orbits Within Orbits

The average distance between the Earth and the moon is about 384,400 km. The average distance between the Earth and the sun is about 150 million kilometers. Assume that the orbit of the Earth around the sun and the orbit of the moon around the Earth are perfectly circular. Using the distances given above, calculate the maximum and minimum distances between the moon and the sun.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Eclipses

eclipse an event in which the shadow of one celestial body falls on another

An **eclipse** happens when the shadow of one celestial body falls on another body. A *lunar eclipse* happens when the Earth comes between the sun and the moon and the shadow of the Earth falls on the moon. A *solar eclipse* happens when the moon comes between the Earth and the sun and the shadow of the moon falls on part of the Earth. **Figure 3** illustrates the positions of the Earth and the moon during a solar eclipse.

The Moon's Orbit Is Tilted!

From our discussion of the moon's phases, you might now be asking the question, Why don't we see solar and lunar eclipses every month? The answer is that the moon's orbit around the Earth is tilted—by about 5°—with respect to the orbit of the Earth around the sun. This tilt is enough to place the moon out of the Earth's shadow for most full-moon phases. The moon's tilted orbit also places the Earth out of the moon's shadow for most new-moon phases. This is why we don't see solar eclipses every month.

Solar Eclipses

Because the moon's orbit is elliptical, the distance between the moon and the Earth changes. During an *annular eclipse,* the moon is farther from the Earth. The disk of the moon does not completely cover the disk of the sun. A thin ring of the sun shows around the moon's outer edge. When the moon is closer to the Earth, the moon appears to be the same size as the sun. During a *total solar eclipse,* the disk of the moon completely covers the disk of the sun, as shown in **Figure 3.** Only the sun's *corona,* or faint outer atmosphere, is visible during a total solar eclipse.

✓ *Reading Check* **Describe what happens during a solar eclipse.**

Figure 3 *On the left is a diagram of the positions of the Earth and the moon during a solar eclipse. On the right is a picture of the sun's outer atmosphere, or* corona, *which is visible only when the entire disk of the sun is blocked by the moon.*

NEVER look directly at the sun! You can permanently damage your eyes.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 4 *On the left, you can see that the moon can have a reddish color during a lunar eclipse. On the right, you can see the positions of Earth and the moon during a lunar eclipse.*

Lunar Eclipses

During a lunar eclipse, the Earth comes between the sun and the moon, as shown in **Figure 4.** So lunar eclipses can happen only during a full moon. As you can see, the view during a lunar eclipse is spectacular. Earth's atmosphere acts like a lens and bends some of the sunlight into the Earth's shadow. When sunlight hits the particles in the atmosphere, the blue light is filtered out. With the blue part of the light removed, most of the remaining light that lights the moon is red.

SECTION Review

Summary

- The moon revolves once around the Earth and rotates once on its axis every 27.3 days.
- The Earth's movement and the moon's orbit cause the phases of the moon.
- A solar eclipse occurs when the shadow of the moon falls on Earth.
- A lunar eclipse occurs when the shadow of Earth falls on the moon.

Using Key Terms

Complete each of the following sentences by choosing the correct term from the word bank.

eclipse phase

1. A _____ happens when the shadow of one celestial body falls on another body.
2. The different appearances of the moon that are due to its position changes are called _____.

Understanding Key Ideas

3. When the sunlit part of the moon appears to get smaller, the moon is said to be
   a. waxing.
   b. phasing.
   c. in an eclipse.
   d. waning.

Math Skills

4. The diameter of the moon is 3,475 km. What is the moon's radius?

Critical Thinking

5. **Applying Concepts** Explain why we always see the same side of the moon.
6. **Identifying Relationships** Describe how the movement of the Earth and the moon's orbit cause the phases of the moon.

SCILINKS® NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: The Earth's Moon
SciLinks code: HSTE490

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 4

Tides, the Sun, and the Moon

If you stand at some ocean shores long enough, you will see the edge of the ocean shrink away from you. Wait longer, and you will see it return to its original place on the shore. Would you believe the moon causes this movement?

READING WARM-UP

Objectives

- Explain tides and their relationship with the Earth, sun, and moon.
- Describe four different types of tides.
- Analyze the relationship between tides and coastal land.

Terms to Learn

tide
tidal range
spring tide
neap tide

READING STRATEGY

Discussion Read this section silently. Write down questions that you have about this section. Discuss your questions in a small group.

You know the movement of the Earth, sun, and moon cause the seasons and the phases of the moon. But did you know that these same movements affect the movement of our oceans? **Tides** are daily changes in the level of ocean water. Tides are influenced by the sun and the moon, as shown in **Figure 1.**

tide the periodic rise and fall of the water level in the oceans and other large bodies of water

The Lure of the Moon

The relationship of the moon to the tides was first discovered more than 2,000 years ago by a Greek explorer named *Pytheas*. But Pytheas and other early investigators could not explain the relationship. A scientific explanation was not given until 1687, when Sir Isaac Newton's theories on the principle of gravitation were published.

The gravity of the moon pulls on every particle of the Earth. But the pull on liquids is much more noticeable than on solids, because liquids move more easily. Even the liquid in an open soft drink is slightly pulled by the moon's gravity.

Reading Check **How does the moon affect things on Earth?** (*See the Appendix for answers to Reading Checks.*)

High Tide and Low Tide

How often tides occur and the difference in tidal levels depend on the position of the moon as it revolves around the Earth. The moon's pull is strongest on the part of the Earth directly facing the moon.

Figure 1 *Although gravitational forces from both the sun and moon continuously pull on the Earth, the moon's gravity is the dominant force on Earth's tides.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

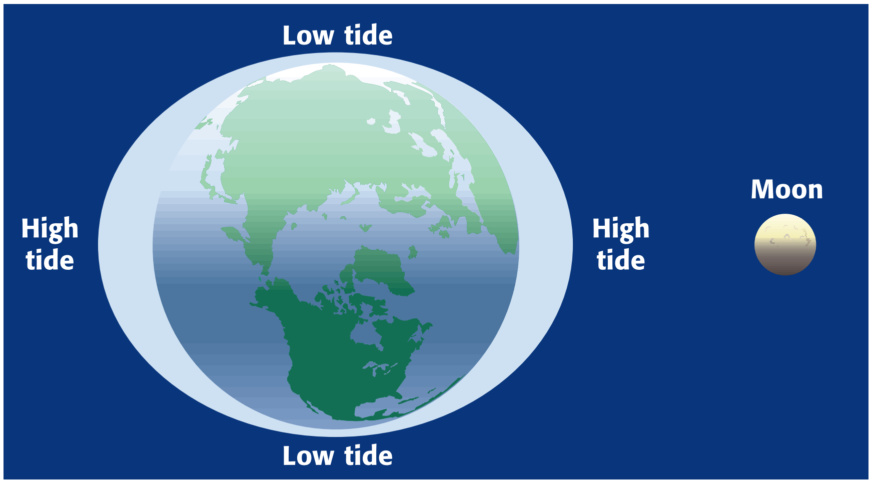


Figure 2 *High tide occurs on the part of Earth that is closest to the moon. At the same time, high tide also occurs on the opposite side of Earth.*

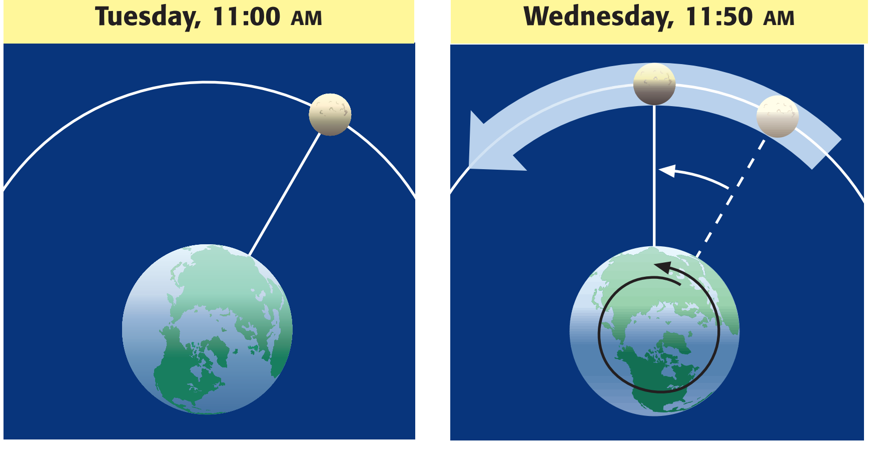
Battle of the Bulge

When part of the ocean is directly facing the moon, the water there bulges toward the moon. At the same time, water on the opposite side of the Earth bulges because of the rotation of the Earth and the motion of the moon around the Earth. These bulges are called *high tides*. Notice in **Figure 2** how the position of the moon causes the water to bulge. Also notice that when high tides occur, water is drawn away from the area between the high tides, which causes *low tides* to form.

Timing the Tides

The rotation of the Earth and the moon's revolution around the Earth determine when tides occur. If the Earth rotated at the same speed that the moon revolves around the Earth, the tides would not alternate between high and low. But the moon revolves around the Earth much more slowly than the Earth rotates. As **Figure 3** shows, a spot on Earth that is facing the moon takes 24 h and 50 m to rotate and face the moon again.

Figure 3 *Tides occur at different locations on Earth because the Earth rotates more quickly than the moon revolves around the Earth.*



CONNECTION TO Language Arts

WRITING SKILL **Mont-St.-Michel Is Sometimes an Island?** Mont-St.-Michel is located off the coast of France. Mont-St.-Michel experiences extreme tides. The tides are so extreme that during high tide, it is an island and during low tide, it is connected to the mainland. Research the history behind Mont-St.-Michel and then write a short story describing what it would be like to live there for a day. Be sure to include a description of Mont-St.-Michel at high tide and at low tide.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Tidal Variations

The sun also affects tides. The sun is much larger than the moon, but the sun is also much farther away. As a result, the sun's influence on tides is less powerful than the moon's influence. The combined forces of the sun and the moon on the Earth result in tidal ranges that vary based on the positions of all three bodies. A **tidal range** is the difference between levels of ocean water at high tide and low tide.

Reading Check **What is a tidal range?**

tidal range the difference in levels of ocean water at high tide and low tide

spring tide a tide of increased range that occurs two times a month, at the new and full moons

neap tide a tide of minimum range that occurs during the first and third quarters of the moon

Spring Tides

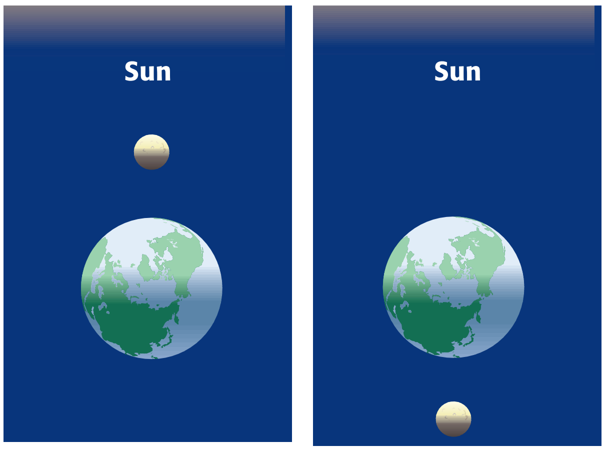
When the sun, Earth, and moon are aligned, spring tides occur. **Spring tides** are tides with the largest daily tidal range and occur during the new and full moons, or every 14 days. The first time spring tides occur is when the moon is between the sun and Earth. The second time spring tides occur is when the moon and the sun are on opposite sides of the Earth. **Figure 4** shows the positions of the sun, Earth, and moon during spring tides.

Neap Tides

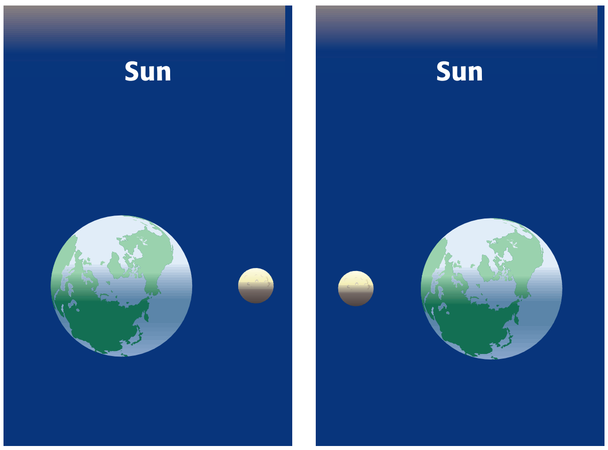
When the sun, Earth, and moon form a 90° angle, neap tides occur. **Neap tides** are tides with the smallest daily tidal range and occur during the first and third quarters of the moon. Neap tides occur halfway between the occurrence of spring tides. When neap tides occur, the gravitational forces on the Earth by the sun and moon work against each other. **Figure 4** shows the positions of the sun, Earth, and moon during neap tides.

Figure 4 **Spring Tides and Neap Tides**

Spring Tides During spring tides, the gravitational forces of the sun and moon pull on the Earth either from the same direction (left) or from opposite directions (right).



Neap Tides During neap tides, the sun and moon are at right angles with respect to the Earth. This arrangement lessens their gravitational effect on the Earth.



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 5 *It's a good thing that the people on this beach (left) knew when high tide occurred (right). These photos show the Bay of Fundy, in New Brunswick, Canada. The Bay of Fundy has the greatest tidal range on Earth.*

Tides and Topography

After a tidal range has been measured, the times that tides occur can be accurately predicted. This information can be useful for people who live near or visit the coast, as shown in **Figure 5.** In some coastal areas that have narrow inlets, movements of water called tidal bores occur. A *tidal bore* is a body of water that rushes up through a narrow bay, estuary, or river channel during the rise of high tide and causes a very sudden tidal rise. Tidal bores occur in coastal areas of China, the British Isles, France, and Canada.

SECTION Review

Summary

- Tides are caused by the gravitational forces of the moon and sun on the Earth.
- The moon's gravity is the main force behind the tides.
- The positions of the sun and moon relative to the position of the Earth cause tidal ranges.
- The four different types of tides are: high tides, low tides, spring tides, and neap tides.

Using Key Terms

1. In your own words, write a definition for each of the following terms: *spring tides* and *neap tides*.

Understanding Key Ideas

2. Tides are at their highest during
   a. spring tide.
   b. neap tide.
   c. a tidal bore.
   d. the daytime.
3. Which tides have minimum tidal range? Which tides have maximum tidal range?
4. What causes tidal ranges?

Math Skills

5. If it takes 24 h and 50 min for a spot on Earth that is facing the moon to rotate to face the moon again, how many minutes does it take?

Critical Thinking

6. **Applying Concepts** How many days pass between the minimum and the maximum of the tidal range in any given area? Explain your answer.
7. **Analyzing Processes** Explain how the position of the moon relates to the occurrence of high tides and low tides.

SCILINKS® NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Tides
SciLinks code: HSM1525

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Skills Practice Lab

Through the Looking Glass

Have you ever looked toward the horizon or up into the sky and wished that you could see farther? Do you think that a telescope might help you see farther? Astronomers use huge telescopes to study the universe. You can build your own telescope to get a glimpse of how these enormous, technologically advanced telescopes help astronomers see distant objects.

OBJECTIVES

Construct a simple model of a refracting telescope.

Observe distant objects by using your telescope.

MATERIALS

- clay, modeling (1 stick)
- convex lens, 3 cm in diameter (2 of different focal length)
- lamp, desk
- paper, white (1 sheet)
- ruler, metric
- scissors
- tape, masking (1 roll)
- toilet-paper tube, cardboard
- wrapping paper tube, cardboard

SAFETY

Procedure

1. Use modeling clay to form a base that holds one of the lenses upright on your desktop. When the lights are turned off, your teacher will turn on a lamp at the front of the classroom. Rotate your lens so that the light from the lamp passes through the lens.
2. Hold the paper so that the light passing through the lens lands on the paper. To sharpen the image of the light on the paper, slowly move the paper closer to or farther from the lens. Hold the paper in the position in which the image is sharpest.
3. Using the metric ruler, measure the distance between the lens and the paper. Record this distance.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

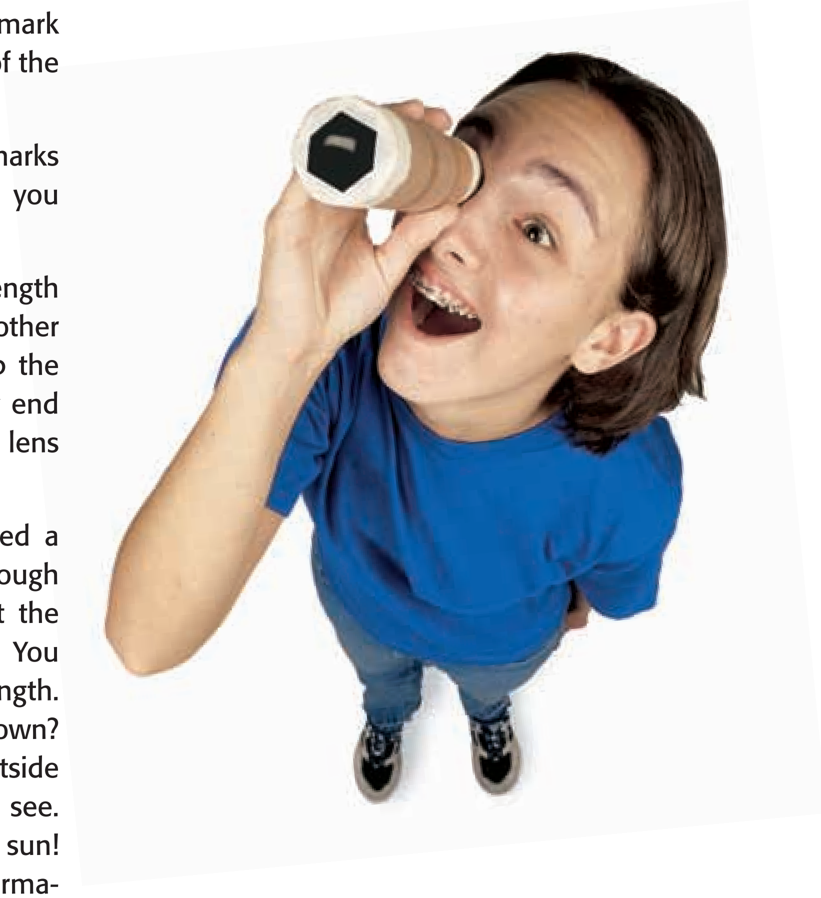
4. How far is the paper from the lens? This distance, called the *focal length,* is the distance that the paper has to be from the lens for the image to be in focus.
5. Repeat steps 1–4 using the other lens.
6. Measuring from one end of the long cardboard tube, mark the focal length of the lens that has the longer focal length. Place a mark 2 cm past this line toward the other end of the tube, and label the mark "Cut."
7. Measuring from one end of the short cardboard tube, mark the focal length of the lens that has the shorter focal length. Place a mark 2 cm past this line toward the other end of the tube, and label the mark "Cut."
8. Shorten the tubes by cutting along the marks labeled "Cut." Wear safety goggles when you make these cuts.
9. Tape the lens that has the longer focal length to one end of the longer tube. Tape the other lens to one end of the shorter tube. Slip the empty end of one tube inside the empty end of the other tube. Be sure that there is one lens at each end of this new, longer tube.
10. Congratulations! You have just constructed a telescope. To use your telescope, look through the short tube (the eyepiece) and point the long end at various objects in the room. You can focus the telescope by adjusting its length. Are the images right side up or upside down? Observe birds, insects, trees, or other outside objects. Record the images that you see. **Caution:** NEVER look directly at the sun! Looking directly at the sun could cause permanent blindness.

Analyze the Results

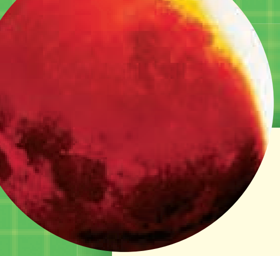
1. **Analyzing Results** Which type of telescope did you just construct: a refracting telescope or a reflecting telescope? What makes your telescope one type and not the other?
2. **Identifying Patterns** What factor determines the focal length of a lens?

Draw Conclusions

3. **Evaluating Results** How would you improve your telescope?



Copyright © by Holt, Rinehart and Winston. All rights reserved.



Chapter Review

USING KEY TERMS

For each pair of terms, explain how the meanings of the terms differ.

1. *rotation* and *revolution*
2. *equinox* and *solstice*
3. *spring tide* and *neap tide*

Complete each of the following sentences by choosing the correct term from the word bank.

orbit	tides
tidal range	eclipse

4. The daily changes of ocean water levels are commonly called ___.
5. A(n) ___ happens when one celestial body casts a shadow on another celestial body.
6. The path that a planet travels around the sun is called the ___ .
7. A(n) ___ is the difference between levels of ocean water between high tide and low tide.

UNDERSTANDING KEY IDEAS

Multiple Choice

8. When might an annular eclipse happen?
   - **a.** every solar eclipse
   - **b.** when the moon's orbit brings it closest to the Earth
   - **c.** only during a full moon
   - **d.** when the moon's orbit takes it farthest from Earth
9. Which of the following happens at the solstices?
   - **a.** The daylight hours equal nighttime hours.
   - **b.** Either spring or fall begins.
   - **c.** The sun is directly above the equator.
   - **d.** Either the Northern or Southern Hemisphere tilts toward the sun.
10. The seasons are caused by
    - **a.** the way the sun hits the Earth at different latitudes.
    - **b.** the Earth's revolution.
    - **c.** the Earth's tilt.
    - **d.** All of the above
11. Planetary orbits are shaped like
    - **a.** solstices.
    - **b.** spirals.
    - **c.** ellipses.
    - **d.** periods of revolution.

Short Answer

12. Describe how latitude affects the amount of seasonal change that an area experiences.
13. What causes the changes in seasons and the length of a day?
14. Compare solar and lunar eclipses.
15. What causes the phases of the moon?
16. Explain why high tide happens on the side of the Earth opposite the moon.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

17 What determines a planet's period of revolution?

18 Why do the sun and the moon appear to move across the sky each day?

19 Do solar eclipses happen during a full moon or a new moon?

20 Why is the tidal range relatively small during a neap tide?

CRITICAL THINKING

21 **Concept Mapping** Use the following terms to create a concept map: *phases, eclipse, revolution, solar eclipse,* and *lunar eclipse*.

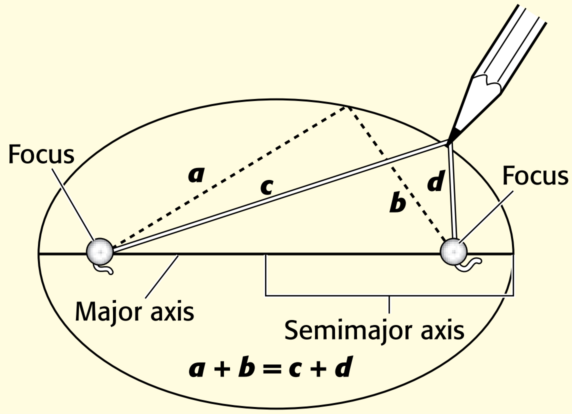
22 **Making Comparisons** How did Newton's law of universal gravitation help explain the work of Johannes Kepler?

23 **Identifying Relationships** Describe Kepler's three laws of motion in your own words. Describe how each law relates to either the revolution, rotation, or orbit of a planetary body.

24 **Analyzing Ideas** Your family is planning to build a home near the beach. Which time, during a period of spring tides or neap tides, is better for choosing the place to build the house?

INTERPRETING GRAPHICS

Use the diagram below to answer the questions that follow.



25 Which of Kepler's laws of motion does the illustration represent?

26 How does the equation shown in the diagram support the law?

27 What is an ellipse's maximum length called?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Standardized Test Preparation

EOG Prep

READING

Read each of the passages below. Then, answer the questions that follow each passage.

Passage 1 In the early Roman calendar, a year had exactly 365 days. The calendar worked well until people realized that the seasons were beginning and ending later each year. To fix this problem, Julius Caesar developed the Julian calendar based on a 365.25-day calendar year. He added 90 days to the year 46 BCE and added an extra day every 4 years. A year in which an extra day is added to the calendar is called a *leap year*. In the mid-1500s, astronomers determined that there are actually 365.2422 days in a year, so Pope Gregory XIII developed the Gregorian calendar. He dropped 10 days from the year 1582 and restricted leap years to years that are divisible by 4 but not by 100 (except for years that are divisible by 400). Today, most countries use the Gregorian calendar.

1. According to the passage, which of the following years is a leap year?

- **A** 46 BCE
- **B** 1582
- **C** 1600
- **D** 1800

2. How long is a year?

- **F** 365 days
- **G** 365.224 days
- **H** 365.2422 days
- **I** 365.25 days

3. Why did Julius Caesar change the early Roman calendar?

- **A** to deal with the fact that the seasons were beginning and ending later each year
- **B** to compete with the Gregorian calendar
- **C** to add an extra day every year
- **D** to shorten the length of a year

Passage 2 The earliest known evidence of astronomical observations is a group of stones near Nabta in southern Egypt that is between 6,000 and 7,000 years old. According to <u>archeoastronomers</u>, some of the stones are positioned such that they would have lined up with the sun during the summer solstice 6,000 years ago. The summer solstice occurs on the longest day of the year. At the Nabta site, the noonday sun is at its zenith (directly overhead) for about three weeks before and after the summer solstice. When the sun is at its zenith, upright objects do not cast shadows. For many civilizations in the Tropics, the zenith sun has had ceremonial significance for thousands of years. The same is probably true for the civilizations that used the Nabta site. Artifacts found at the site near Nabta suggest that the site was created by African cattle herders. These people probably used the site for many purposes, including trade, social bonding, and ritual.

1. In the passage, what does *archeoastronomer* mean?

- **A** an archeologist who studies Egyptian culture
- **B** an astronomer who studies the zenith sun
- **C** an archeologist who studies ancient astronomy
- **D** an astronomer who studies archeologists

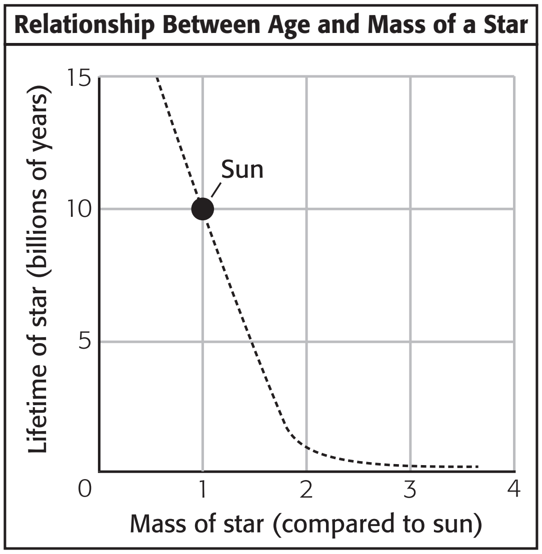
2. Why don't upright objects cast a shadow when the sun is at its zenith?

- **F** because the sun is directly overhead
- **G** because the summer solstice is occurring
- **H** because the sun is below the horizon
- **I** because the sun is at its zenith on the longest day of the year

Copyright © by Holt, Rinehart and Winston. All rights reserved.

INTERPRETING GRAPHICS

The graph below shows the relationship between a star's age and mass. Use the graph below to answer the questions that follow.



1. How long does a star that has 1.2 times the mass of the sun live?

A 10 billion years
B 8 billion years
C 6 billion years
D 5 billion years

2. How long does a star that has 2 times the mass of the sun live?

F 4 billion years
G 1 billion years
H 10 billion years
I 5 billion years

3. If the sun's mass was reduced by half, how long would the sun live?

A 2 billion years
B 8 billion years
C 10 billion years
D more than 15 billion years

4. According to the graph, how long is the sun predicted to live?

F 15 billion years
G 10 billion years
H 5 billion years
I 2 billion years

MATH

Read each question below, and choose the best answer.

1. If light travels 300,000 km/s, how long does light reflected from Mars take to reach Earth when Mars is 65,000,000 km away ?

A 22 s
B 217 s
C 2,170 s
D 2,200 s

2. Star A is 8 million kilometers from star B. What is this distance expressed in meters?

F 0.8 m
G 8,000 m
H 8×10^6 m
I 8×10^9 m

3. If each hexagonal mirror in the Keck Telescopes is 1.8 m across, how many mirrors would be needed to create a light-reflecting surface that is 10.8 m across?

A 3.2
B 5
C 6
D 6.2

4. The mass of the known universe is about 10^{23} solar masses, which is 10^{50} metric tons. How many metric tons is one solar mass?

F 10^{27} solar masses
G 10^{27} metric tons
H 10^{73} solar masses
I 10^{73} metric tons

5. You are studying an image made by the *Hubble Space Telescope*. If you observe 90 stars in an area that is 1 cm^2, which of the following estimates is the best estimate for the number of stars in 15 cm^2?

A 700
B 900
C 1,200
D 1,350

Standardized Test Preparation

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Science in Action

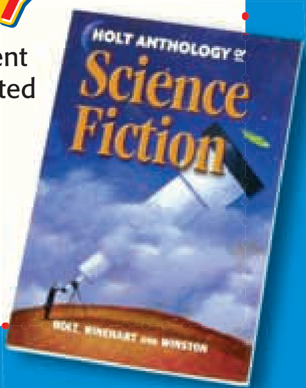
Science, Technology, and Society

Light Pollution

When your parents were your age, they could look up at the night sky and see many more stars than you can now. In a large city, seeing more than 50 stars or planets in the night sky can be difficult. Light pollution is a growing—or you could say "glowing"—problem. If you have ever seen a white glow over the horizon in the night sky, you have seen the effects of light pollution. Most light pollution comes from outdoor lights that are excessively bright or misdirected. Light pollution not only limits the number of stars that the average person can see but also limits what astronomers can detect. Light pollution affects migrating animals, too. Luckily, there are ways to reduce light pollution. The International Dark Sky Association is working to reduce light pollution around the world. Find out how you can reduce light pollution in your community or home.

Math ACTIVITY

A Virginia high school student named Jennifer Barlow started "National Dark Sky Week." If light pollution is reduced for 1 week each year, for what percentage of the year would light pollution be reduced?



Science Fiction

"Why I Left Harry's All-Night Hamburgers" by Lawrence Watt-Evans

The main character was 16, and he needed to find a job. So, he began working at Harry's All-Night Hamburgers. His shift was from midnight to 7:30 A.M. so that he could still go to school. Harry's All-Night Hamburgers was pretty quiet most nights, but once in a while some unusual characters came by. For example, one guy came in dressed for Arctic weather even though it was April. Then there were the folks who parked a very strange vehicle in the parking lot for anyone to see. The main character starts questioning the visitors, and what he learns startles and fascinates him. Soon, he's thinking about leaving Harry's. Find out why when you read "Why I Left Harry's All-Night Hamburgers," in the *Holt Anthology of Science Fiction*.

Language Arts ACTIVITY

WRITING SKILL The main character in the story learns that Earth is a pretty strange place. Find out about some of the places mentioned in the story, and create an illustrated travel guide that describes some of the foreign places that interest you.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

People in Science

Janis Davis-Street

NASA Nutritionist Do astronauts eat shrimp cocktail in space? Yes, they do! Shrimp cocktail is nutritious and tastes so good that it is one of the most popular foods in the space program. And eating a proper diet helps astronauts stay healthy while they are in space.

But who figures out what astronauts need to eat? Janis Davis-Street is a nutritionist and laboratory supervisor for the Nutritional Biochemistry Laboratory at the Johnson Space Center in Houston, Texas. She was born in Georgetown, Guyana, on the northeastern coast of South America. She was educated in Canada.

Davis-Street is part of a team that uses their knowledge of nutrition, biology, and chemistry to figure out the nutritional requirements for spaceflight. For example, they determine how many calories and other nutrients each astronaut needs per day during spaceflight.

The Nutritional Biochemistry Laboratory's work on the space shuttle missions and *Mir* space station developed into tests that allow NASA to help ensure astronaut health before, during, and after flight. These tests are important for understanding how the human body adapts to long space missions, and for determining whether treatments for preventing bone and muscle loss during spaceflight are working.

Social Studies ACTIVITY

WRITING SKILL Scientists from more than 30 countries have been on space missions. Research which countries have provided astronauts or cosmonauts for space missions. Using a map, place self-stick notes on countries that have provided scientists for space missions. Write the names of the appropriate scientists on the self-stick notes.

go.hrw.com

To learn more about these Science in Action topics, visit go.hrw.com and type in the keyword HT5R6ESMF.

Current Science

Check out Current Science® articles related to this chapter by visiting go.hrw.com. Just type in the keyword HZ5CS20.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

10

Formation of the Solar System

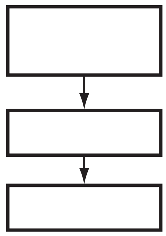
About the PHOTO

The Orion Nebula, a vast cloud of dust and gas that is 35 trillion miles wide, is part of the familiar Orion constellation. Here, swirling clouds of dust and gas give birth to systems like our own solar system.

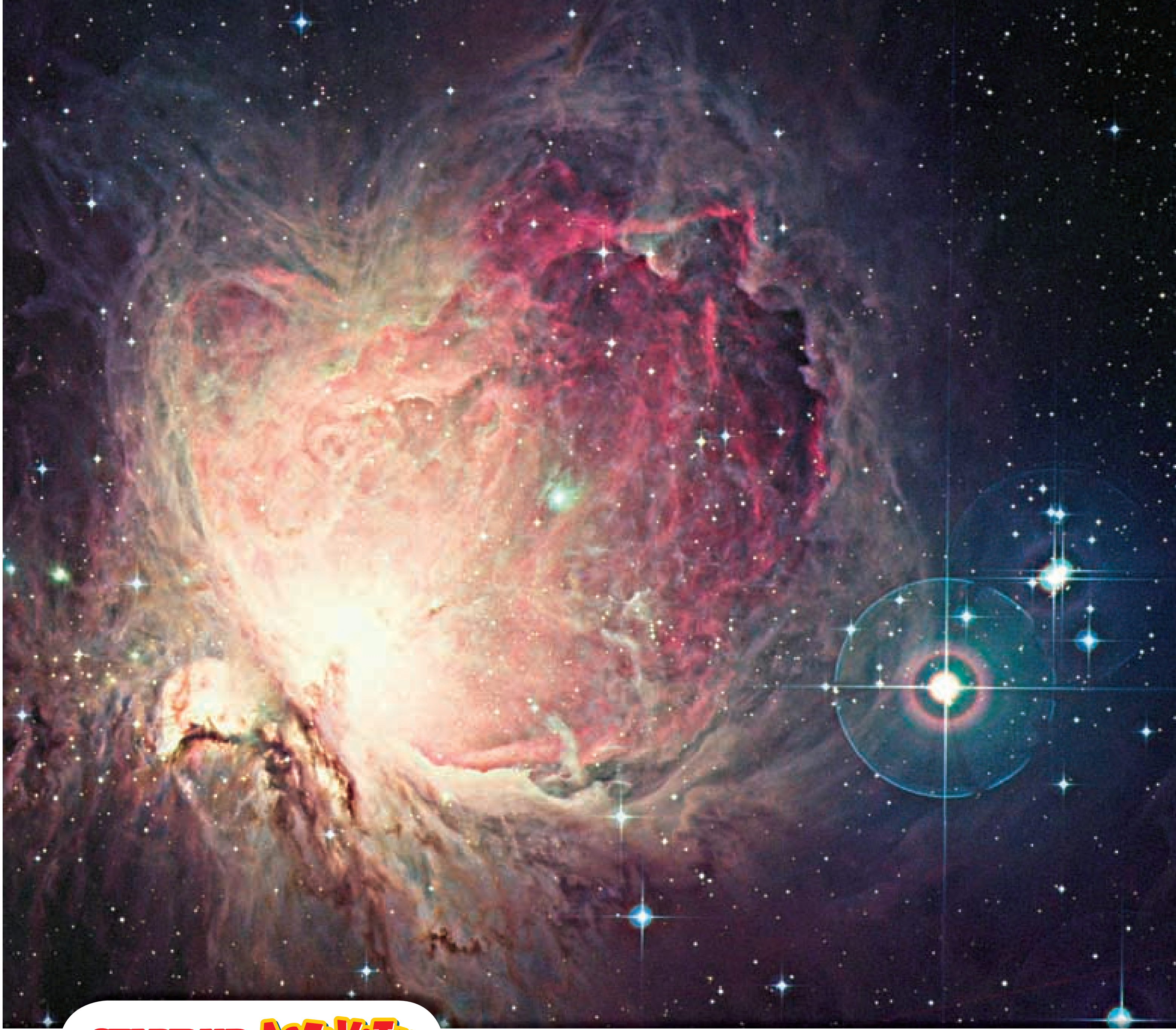
PRE-READING ACTIVITY

Graphic Organizer

Chain-of-Events Chart Before you read the chapter, create the graphic organizer entitled "Chain-of-Events Chart" described in the **Study Skills** section of the Appendix. As you read the chapter, fill in the chart with details about each step of the formation of the solar system.



Copyright © by Holt, Rinehart and Winston. All rights reserved.



START-UP ACTIVITY

Strange Gravity

If you drop a heavy object, will it fall faster than a lighter one? According to the law of gravity, the answer is no. In 1971, *Apollo 15* astronaut David Scott stood on the moon and dropped a feather and a hammer. Television audiences were amazed to see both objects strike the moon's surface at the same time. Now, you can perform a similar experiment.

Procedure

1. Select **two pieces of identical notebook paper.** Crumple one piece of paper into a ball.
2. Place the flat piece of paper on top of a **book** and the paper ball on top of the flat piece of paper.
3. Hold the book waist high, and then drop it to the floor.

Analysis

1. Which piece of paper reached the bottom first? Did either piece of paper fall slower than the book? Explain your observations.
2. Now, hold the crumpled paper in one hand and the flat piece of paper in the other. Drop both pieces of paper at the same time. Besides gravity, what affected the speed of the falling paper? Record your observations.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 1

Galaxies

Your address is part of a system that is much larger than your street, city, state, country, and even the planet Earth. You also live in the Milky Way galaxy, which is among many other galaxies located far, far away.

READING WARM-UP

Objectives

- Explain how distance is measured in space.
- Identify three types of galaxies.
- Describe the contents and characteristics of galaxies.
- Explain why looking at distant galaxies reveals what young galaxies looked like.

Terms to Learn

light-year	globular cluster
galaxy	open cluster
nebula	quasar

READING STRATEGY

Reading Organizer As you read this section, make a table comparing the different types of galaxies.

How far away is the next galaxy? How far away are the stars? Over the years, many scientists have asked this question. Scientists now know that the universe is huge and difficult to measure. It's too big to measure with a meterstick!

Measuring Distance in Space

The stars are much farther away than the planets are. In fact, stars are so distant that a new unit of length—the light-year—was created to measure their distance. A **light-year** is a unit of length equal to the distance that light travels in 1 year. One light-year is equal to about 9.46 trillion kilometers! The farthest objects that we can observe are more than 10 billion light-years away. Although the stars may appear to be at similar distances from Earth, their distances vary greatly. For example, **Figure 1** shows how far away the stars that make up part of Orion are.

When you think about the universe and all of the objects that it contains, considering scale is important. For example, stars appear to be very small in the night sky. But we know that most stars are a lot larger than Earth. **Figure 2** will help you understand the scale of objects in the universe.

light-year the distance that light travels in one year; about 9.46 trillion kilometers

Reading Check How far does light travel in 1 year? (*See the Appendix for answers to Reading Checks.*)

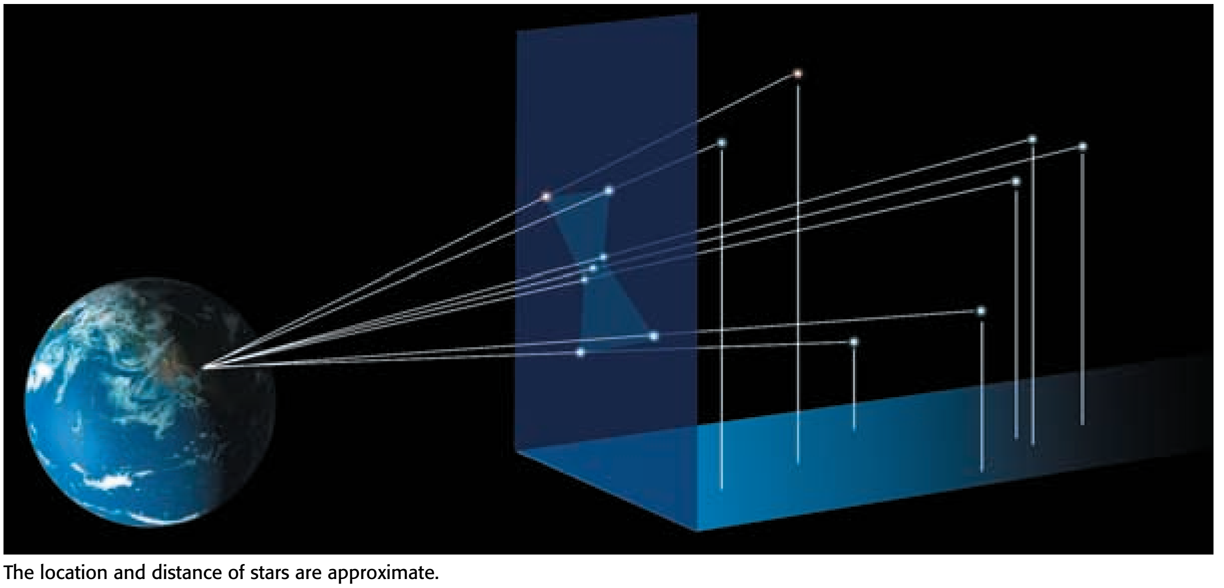


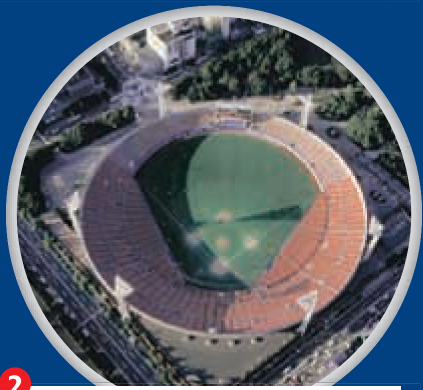
Figure 1 *From Earth, the stars seem to be close to one another, but they are actually far apart.*

The location and distance of stars are approximate.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

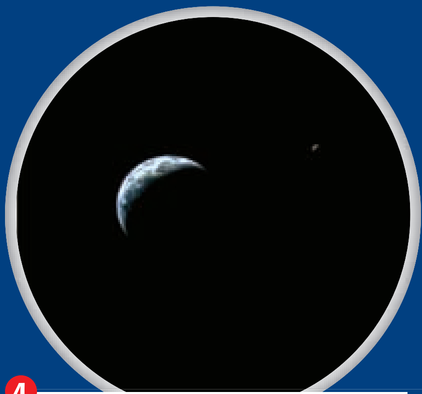
Figure 2 From Home Plate to 10 Million Light-Years Away

1 Let's start with home plate in a baseball stadium. You are looking down from a distance of about 10 m.



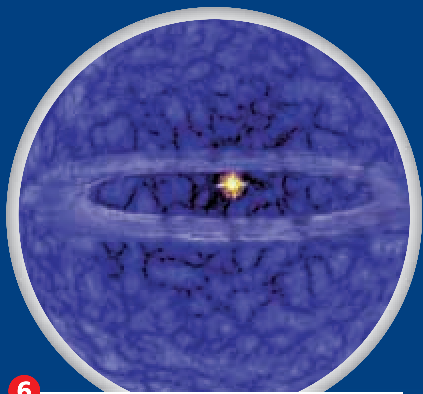
2 At 1,000 m (1 km) away, you can see the baseball stadium and the surrounding neighborhood.

3 At 100 km away, you see the city that contains the stadium and the countryside around the city.



4 At 100,000 km away, you can see the Earth and the moon.

5 At 1,500,000,000 km (83 light-minutes) away, you can look back at the sun and the inner planets.



6 At 150 light-days, the solar system, surrounded by a cloud of comets and other icy debris, can be seen.

7 By the time you are 10 light-years away, the sun resembles any other star in space.

8 At 1 million light-years away, our galaxy looks like the Andromeda galaxy, a cloud of stars set in the blackness of space.

9 At 10 million light-years away, you can see a handful of galaxies called the *Local Group*.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 3 *Edwin Hubble, the astronomer for whom the Hubble Space Telescope is named, began studying galaxies in the 1920s.*

Types of Galaxies

The stars may be far away, but with tools such as telescopes, astronomers have been able to study stars and galaxies even billions of light-years away. A **galaxy** is a large group of stars, dust, and gas. Galaxies come in a variety of sizes and shapes. The largest galaxies contain more than a trillion stars.

There are many types of galaxies. An astronomer named Edwin Hubble, shown in **Figure 3,** began to classify galaxies, mostly by their shapes, in the 1920s. Astronomers still use the galaxy classification that Hubble developed.

galaxy a collection of stars, dust, and gas bound together by gravity

Spiral Galaxies

When someone says the word *galaxy,* most people probably think of a spiral galaxy. *Spiral galaxies,* such as the one shown in **Figure 4,** have a bulge at the center and spiral arms. The spiral arms are made up of gas, dust, and new stars that have formed in these denser regions of gas and dust.

The Milky Way

It is hard to tell what type of galaxy we live in because the gas, dust, and stars keep astronomers from having a good view of our galaxy. Observing other galaxies and making measurements inside our galaxy, the Milky Way, has led astronomers to think that our solar system is in a spiral galaxy.

Figure 4 **Types of Galaxies**

Spiral Galaxy
The Andromeda galaxy is a spiral galaxy that looks similar to what our galaxy, the Milky Way, is thought to look like.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Elliptical Galaxies

About one-third of all galaxies are simply massive blobs of stars. Many look like spheres, and others are more stretched out. Because we don't know how they are oriented, some of these galaxies could be cucumber shaped, with the round end facing our galaxy. These galaxies are called *elliptical galaxies*. Elliptical galaxies usually have very bright centers and very little dust and gas. Elliptical galaxies contain mostly old stars. Because there is so little free-flowing gas in an elliptical galaxy, few new stars form. Some elliptical galaxies, such as M87, shown in **Figure 4,** are huge and are called *giant elliptical galaxies*. Other elliptical galaxies are much smaller and are called *dwarf elliptical galaxies*.

Irregular Galaxies

When Hubble first classified galaxies, he had a group of leftovers. He named the leftovers "irregulars." *Irregular galaxies* are galaxies that don't fit into any other class. As their name suggests, their shape is irregular. Many of these galaxies, such as the Large Magellanic Cloud, shown in **Figure 4,** are close companions of large spiral galaxies. The large spiral galaxies may be distorting the shape of these irregular galaxies.

Reading Check What are irregular galaxies?

CONNECTION TO Language Arts

WRITING SKILL **Alien Observer** As you read earlier, it's hard to tell what type of galaxy we live in because the gas, dust, and stars keep us from having a good view. But our galaxy might look different to an alien observer. Write a short story describing how our galaxy would look to an alien observer in another galaxy.

Elliptical Galaxy Unlike the Milky Way, the galaxy known as M87 has no spiral arms.

Irregular Galaxy The Large Magellanic Cloud, an irregular galaxy, is located within our galactic neighborhood.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Contents of Galaxies

Galaxies are composed of billions of stars and some planetary systems, too. Some of these stars form large features, such as gas clouds and star clusters, as shown in **Figure 5.**

Gas Clouds

nebula a large cloud of dust and gas in interstellar space; a region in space where stars are born or where stars explode at the end of their lives

globular cluster a tight group of stars that looks like a ball and contains up to 1 million stars

open cluster a group of stars that are close together relative to surrounding stars

quasar a very luminous, starlike object that generates energy at a high rate; quasars are thought to be the most distant objects in the universe

The Latin word for "cloud" is *nebula*. In space, **nebulas** (or nebulae) are large clouds of gas and dust. Some types of nebulas glow, while others absorb light and hide stars. Still, other nebulas reflect starlight and produce some amazing images. Some nebulas are regions in which new stars form. **Figure 5** shows part of the Eagle nebula. Spiral galaxies usually contain nebulas, but elliptical galaxies contain very few.

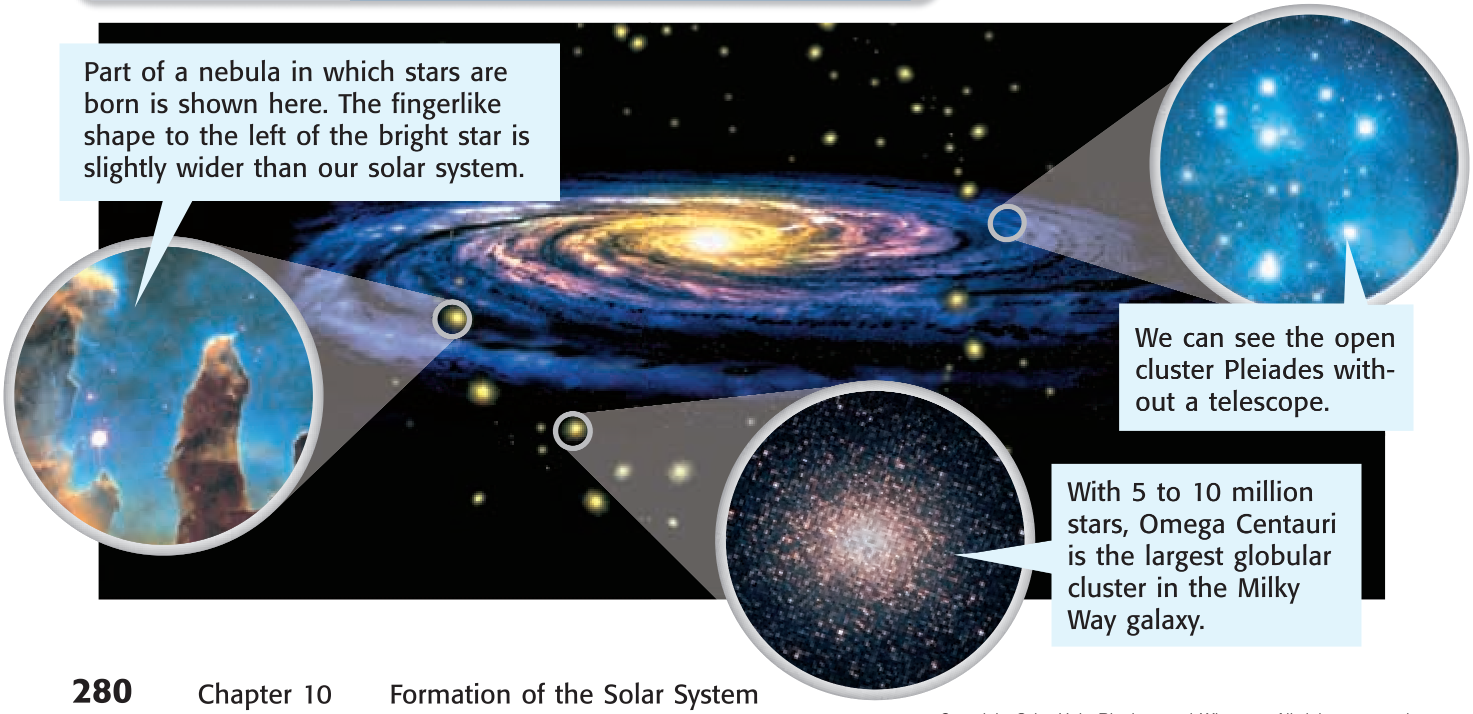
Star Clusters

Globular clusters are groups of older stars. A **globular cluster** is a group of stars that looks like a ball, as shown in **Figure 5.** There may be up to one million stars in a globular cluster. Globular clusters are located in a spherical *halo* that surrounds spiral galaxies such as the Milky Way. Globular clusters are also common near giant elliptical galaxies.

Open clusters are groups of closely grouped stars that are usually located along the spiral disk of a galaxy. Newly formed open clusters have many bright blue stars, as shown in **Figure 5.** There may be a few hundred to a few thousand stars in an open cluster.

Reading Check **What is the difference between a globular cluster and an open cluster?**

Figure 5 **Gas Clouds and Star Clusters**



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Origin of Galaxies

Scientists can learn about the early universe by observing objects that are extremely far away. Because it takes time for light to travel through space, looking through a telescope is like looking back in time. Looking at distant galaxies can help scientists understand what early galaxies were like.

Among the most distant objects that scientists study are quasars, such as the one in **Figure 6.** **Quasars** are star-like sources of light that are extremely far away. They are among the most powerful energy sources in the universe. Some scientists think that quasars may be caused by massive black holes in the cores of young galaxies.

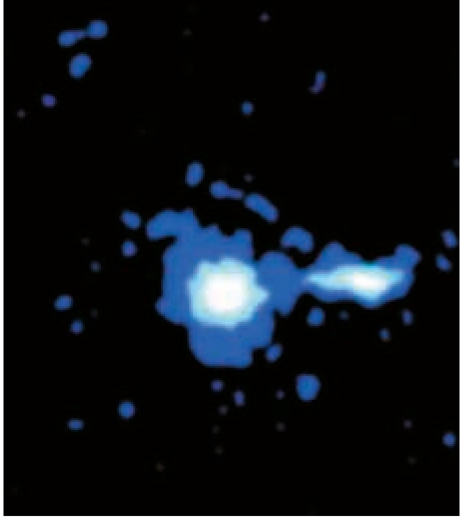


Figure 6 *The quasar known as PKS 0637-752 is as massive as 10 billion suns.*

SECTION Review

Summary

- Scientists use light-years to measure distances in space.
- Edwin Hubble classified galaxies according to their shape, such as spiral, elliptical, and irregular.
- Nebulas are large clouds of gas and dust. Globular clusters are tightly grouped stars. Open clusters are closely grouped stars.
- Scientists look at distant galaxies to learn what early galaxies looked like.

Using Key Terms

1. Use the following terms in the same sentence: *nebula, globular cluster,* and *open cluster.*

Understanding Key Ideas

2. Arrange the following galaxies in order of decreasing size: spiral, giant elliptical, dwarf elliptical, and irregular.
3. All of the following are shapes used to classify galaxies EXCEPT
   a. elliptical.
   b. irregular.
   c. spiral.
   d. triangular.
4. What was Edwin Hubble's contribution to astronomy?
5. Why did scientists develop the light-year to measure distances in space?
6. Based on observations of other galaxies and measurements inside our galaxy, what type of galaxy do astronomers think the Milky Way is?

Critical Thinking

7. **Making Comparisons** Describe the difference between an elliptical galaxy and a globular cluster.
8. **Identifying Relationships** Explain how looking through a telescope is like looking back in time.

Math Skills

9. The quasar known as PKS 0637-752 is 6 billion light-years away from Earth. The North Star is 431 light-years away from Earth. What is the ratio of the distances from Earth (in kilometers) of these two celestial objects? (Hint: One light-year is equal to 9.46 trillion kilometers.)

SCILINKS® NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Galaxies
SciLinks code: HSM0632

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 2

A Solar System Is Born

READING WARM-UP

Objectives

- Explain the relationship between gravity and pressure in a nebula.
- Describe how the solar system formed.

Terms to Learn

solar nebula

READING STRATEGY

Reading Organizer As you read this section, make a flowchart of the steps of the formation of a solar system.

As you read this sentence, you are traveling at a speed of about 30 km/s around an incredibly hot star shining in the vastness of space!

Earth is not the only planet orbiting the sun. In fact, Earth has eight fellow travelers in its cosmic neighborhood. The solar system includes a star we call the sun, nine planets, and many moons and small bodies that travel around the sun. For almost 5 billion years, planets have been orbiting the sun. But how did the solar system come to be?

The Solar Nebula

All of the ingredients for building planets, moons, and stars are found in the vast, seemingly empty regions of space between the stars. Just as there are clouds in the sky, there are clouds in space. As you learned earlier, these clouds are called *nebulas*. Nebulas (or nebulae) are mixtures of gases—mainly hydrogen and helium—and dust made of elements such as carbon and iron. Although nebulas are normally dark and invisible to optical telescopes, they can be seen when nearby stars illuminate them. So, how can a cloud of gas and dust such as the Horsehead Nebula, shown in **Figure 1,** form planets and stars? To answer this question, you must explore two forces that interact in nebulas—gravity and pressure.

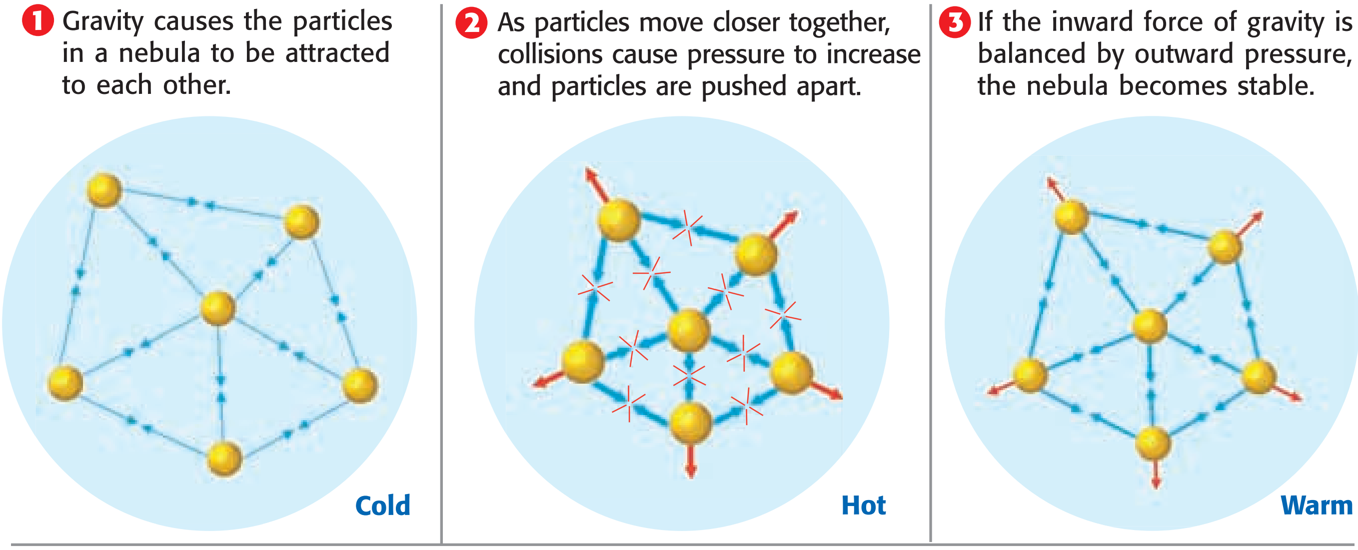
Gravity Pulls Matter Together

The gas and dust that make up nebulas are made of matter. The matter of a nebula is held together by the force of gravity. In most nebulas, there is a lot of space between the particles. In fact, nebulas are less dense than air! Thus, the gravitational attraction between the particles in a nebula is very weak. The force is just enough to keep the nebula from drifting apart.

Figure 1 *The Horsehead Nebula is a cold, dark cloud of gas and dust. But observations suggest that it is also a site where stars form.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 2 **Gravity and Pressure in a Nebula**



Pressure Pushes Matter Apart

If gravity pulls on all of the particles in a nebula, why don't nebulas slowly collapse? The answer has to do with the relationship between temperature and pressure in a nebula. *Temperature* is a measure of the average kinetic energy, or the energy of motion, of the particles in an object. If the particles in a nebula have little kinetic energy, they move slowly and the temperature of the cloud is very low. If the particles move fast, the temperature of the cloud is high. As particles move around, they sometimes crash into each other. As shown in **Figure 2,** these collisions cause particles to push away from each other, which creates *pressure*. If you have ever blown up a balloon, you understand how pressure works—pressure keeps a balloon from collapsing. In a nebula, outward pressure balances the inward gravitational pull and keeps the cloud from collapsing.

Upsetting the Balance

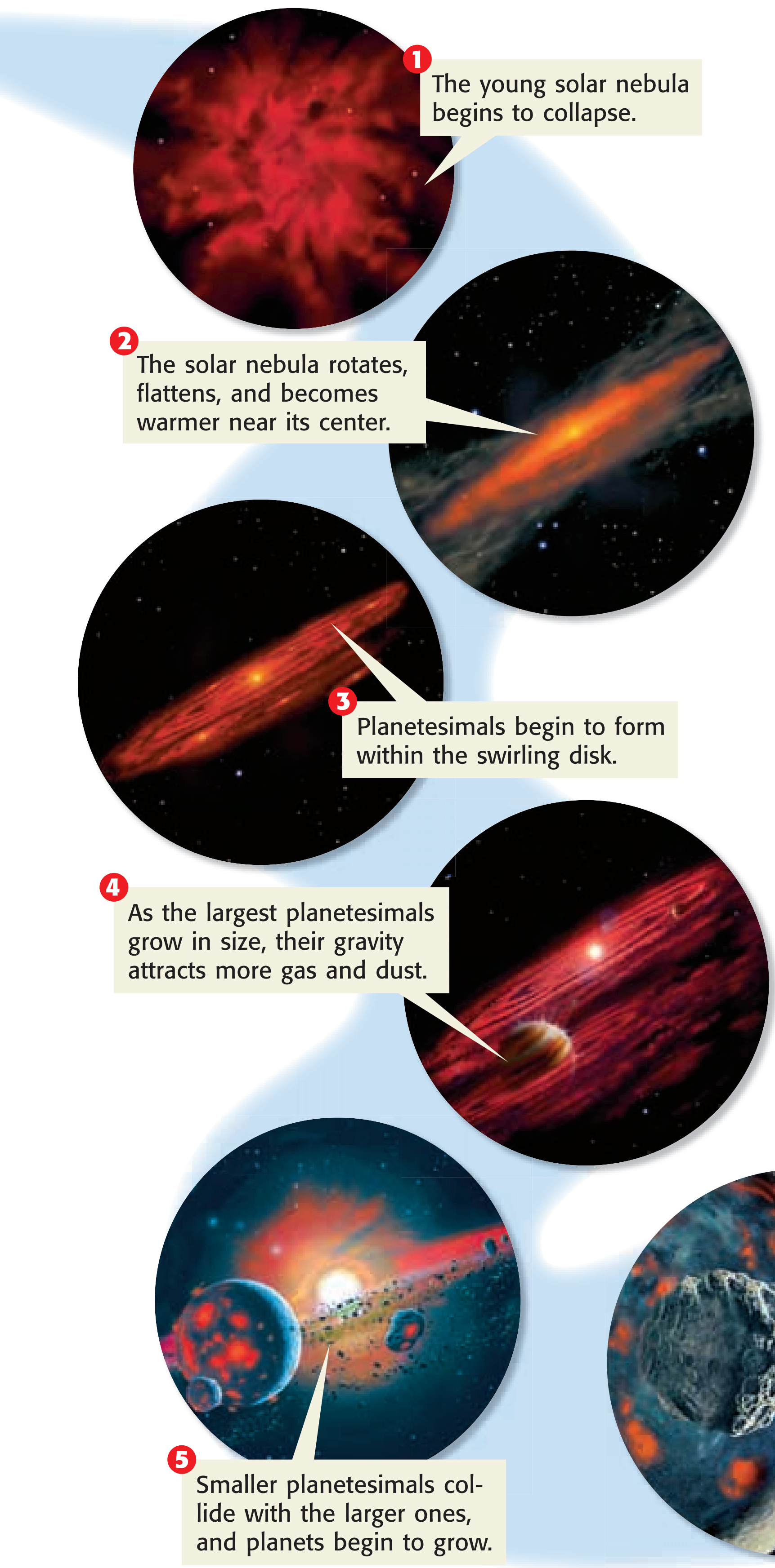
The balance between gravity and pressure in a nebula can be upset if two nebulas collide or a nearby star explodes. These events compress, or push together, small regions of a nebula called *globules,* or gas clouds. Globules can become so dense that they contract under their own gravity. As the matter in a globule collapses inward, the temperature increases and the stage is set for stars to form. The **solar nebula**—the cloud of gas and dust that formed our solar system—may have formed in this way.

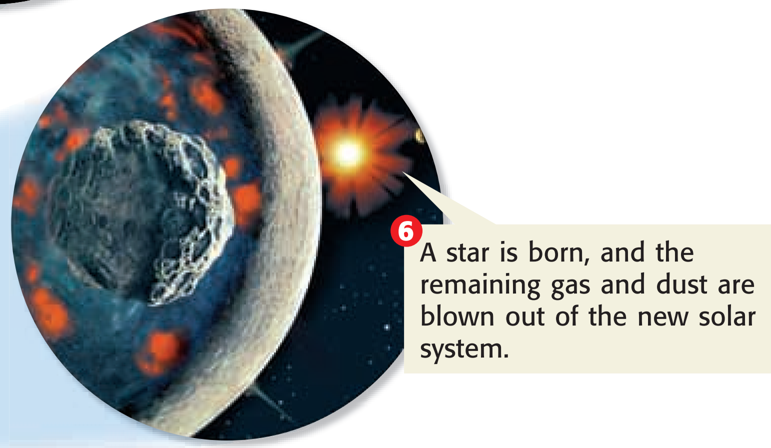
solar nebula the cloud of gas and dust that formed our solar system

Reading Check **What is the solar nebula?** (*See the Appendix for answers to Reading Checks.*)

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 3 **The Formation of the Solar System**





How the Solar System Formed

The events that may have led to the formation of the solar system are shown in **Figure 3.** After the solar nebula began to collapse, it took about 10 million years for the solar system to form. As the nebula collapsed, it became denser and the attraction between the gas and dust particles increased. The center of the cloud became very dense and hot. Over time, much of the gas and dust began to rotate slowly around the center of the cloud. While the tremendous pressure at the center of the nebula was not enough to keep the cloud from collapsing, this rotation helped balance the pull of gravity. Over time, the solar nebula flattened into a rotating disk. All of the planets still follow this rotation.

From Planetesimals to Planets

As bits of dust circled the center of the solar nebula, some collided and stuck together to form golf ball–sized bodies. These bodies eventually drifted into the solar nebula, where further collisions caused them to grow to kilometer-wide bodies. As more collisions happened, some of these bodies grew to hundreds of kilometers wide. The largest of these bodies are called *planetesimals,* or small planets. Some of these planetesimals are part of the cores of current planets, while others collided with forming planets to create enormous craters.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Gas Giant or Rocky Planet?

The largest planetesimals formed near the outside of the rotating solar disk, where hydrogen and helium were located. These planetesimals were far enough from the solar disk that their gravity could attract the nebula gases. These outer planets grew to huge sizes and became the gas giants—Jupiter, Saturn, Uranus, and Neptune. Closer to the center of the nebula, where Mercury, Venus, Earth, and Mars formed, temperatures were too hot for gases to remain. Therefore, the inner planets in our solar system are made mostly of rocky material.

Reading Check **Which planets are gas giants?**

The Birth of a Star

As the planets were forming, other matter in the solar nebula was traveling toward the center. The center became so dense and hot that hydrogen atoms began to fuse, or join, to form helium. Fusion released huge amounts of energy and created enough outward pressure to balance the inward pull of gravity. At this point, when the gas stopped collapsing, our sun was born and the new solar system was complete!

CONNECTION TO Language Arts

WRITING SKILL **Eyewitness Account** Research information on the formation of the outer planets, inner planets, and the sun. Then, imagine that you witnessed the formation of the planets and sun. Write a short story describing your experience.

SECTION Review

Summary

- The solar system formed out of a vast cloud of gas and dust called the *nebula*.
- Gravity and pressure were balanced until something upset the balance. Then, the nebula began to collapse.
- Collapse of the solar nebula caused heating at the center, while planetesimals formed in surrounding space.
- The central mass of the nebula became the sun. Planets formed from the surrounding materials.

Using Key Terms

1. In your own words, write a definition for the following term: *solar nebula*.

Understanding Key Ideas

2. What is the relationship between gravity and pressure in a nebula?
   a. Gravity reduces pressure.
   b. Pressure balances gravity.
   c. Pressure increases gravity.
   d. None of the above
3. Describe how our solar system formed.
4. Compare the inner planets with the outer planets.

Math Skills

5. If the planets, moons, and other bodies make up 0.15% of the solar system's mass, what percentage does the sun make up?

Critical Thinking

6. **Evaluating Hypotheses** Pluto, the outermost planet, is small and rocky. Some scientists argue that Pluto is a captured asteroid, not a planet. Use what you know about how solar systems form to evaluate this hypothesis.
7. **Making Inferences** Why do all of the planets go around the sun in the same direction, and why do the planets lie on a relatively flat plane?

SCILINKS® NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: The Planets
SciLinks code: HSM1152

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 3

The Sun: Our Very Own Star

Can you imagine what life on Earth would be like if there were no sun? Without the sun, life on Earth would be impossible!

Energy from the sun lights and heats Earth's surface. Energy from the sun even drives the weather. Making up more than 99% of the solar system's mass, the sun is the dominant member of our solar system. The sun is basically a large ball of gas made mostly of hydrogen and helium held together by gravity. But what does the inside of the sun look like?

The Structure of the Sun

Although the sun may appear to have a solid surface, it does not. When you see a picture of the sun, you are really seeing through the sun's outer atmosphere. The visible surface of the sun starts at the point where the gas becomes so thick that you cannot see through it. As **Figure 1** shows, the sun is made of several layers.

READING WARM-UP

Objectives

- Describe the basic structure and composition of the sun.
- Explain how the sun generates energy.
- Describe the surface activity of the sun, and identify how this activity affects Earth.

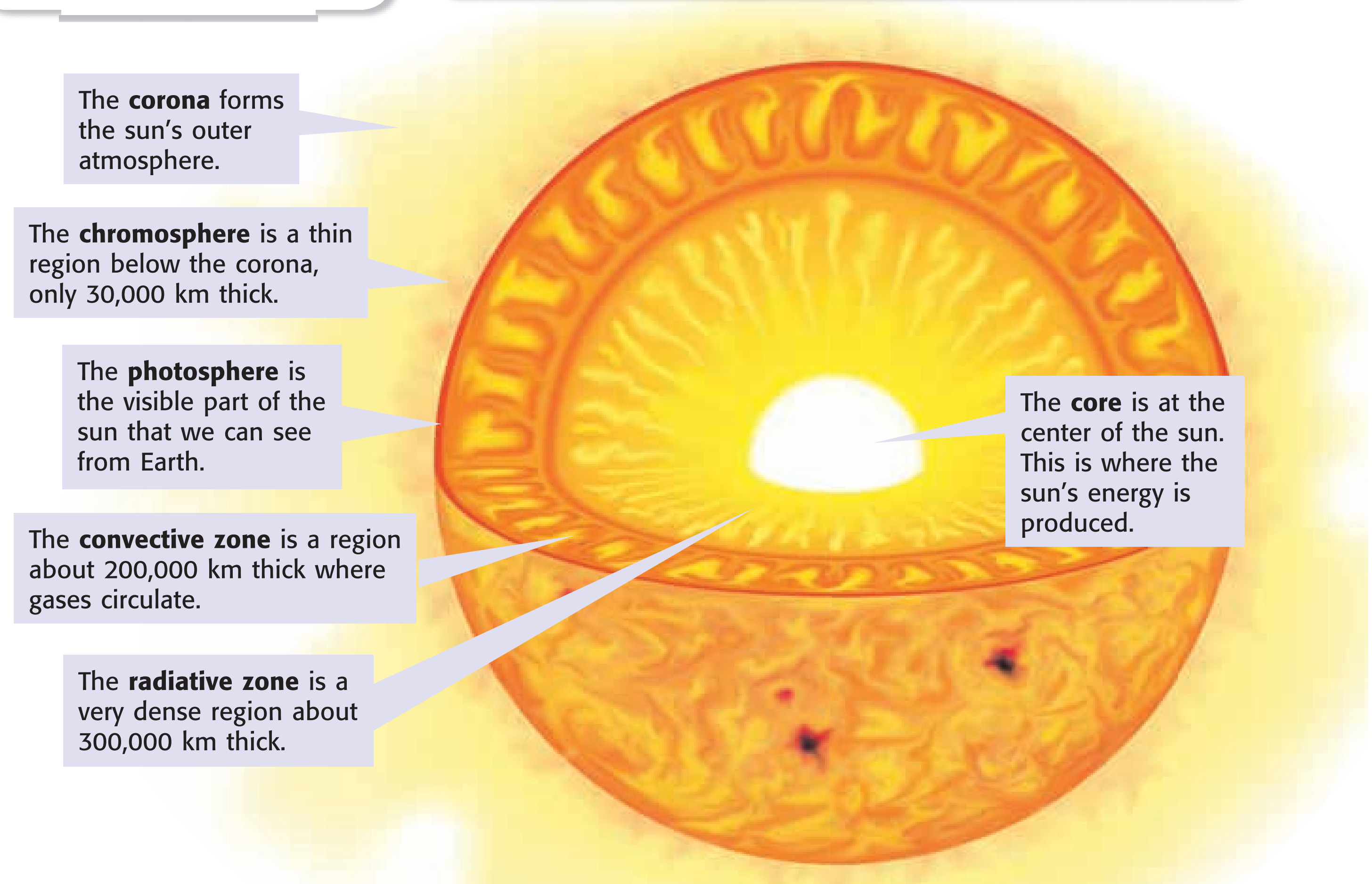
Terms to Learn

nuclear fusion
sunspot

READING STRATEGY

Reading Organizer As you read this section, create an outline of the section. Use the headings from the section in your outline.

Figure 1 The Structure and Atmosphere of the Sun



Copyright © by Holt, Rinehart and Winston. All rights reserved.

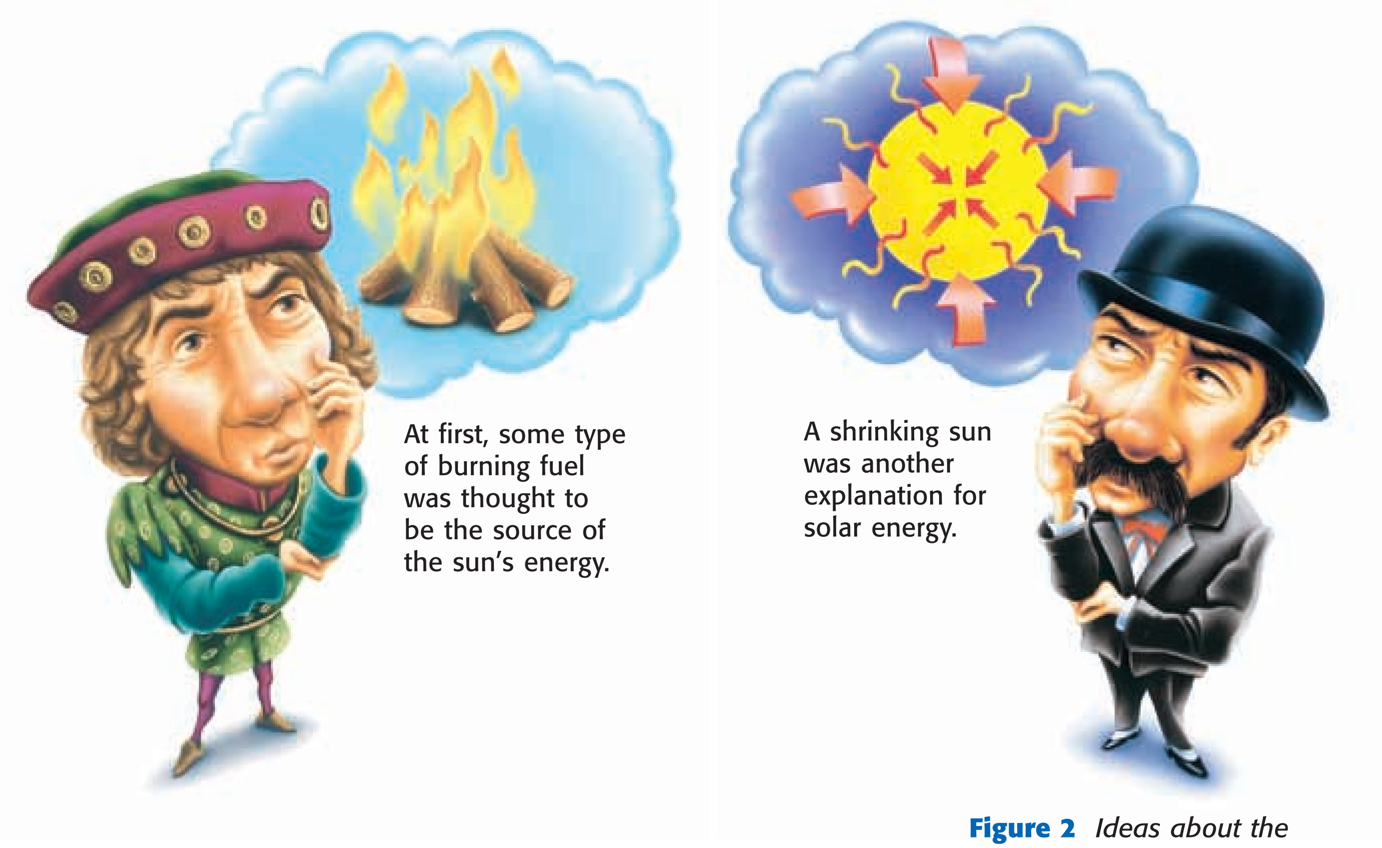


Figure 2 *Ideas about the source of the sun's energy have changed over time.*

Energy Production in the Sun

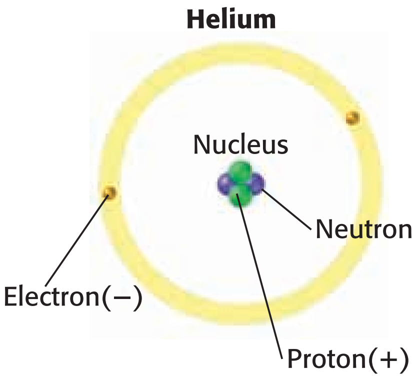
The sun has been shining on Earth for about 4.6 billion years. How can the sun stay hot for so long? And what makes it shine? **Figure 2** shows two theories that were proposed to answer these questions. Many scientists thought that the sun burned fuel to generate its energy. But the amount of energy that is released by burning would not be enough to power the sun. If the sun were simply burning, it would last for only 10,000 years.

Burning or Shrinking?

It eventually became clear to scientists that burning wouldn't last long enough to keep the sun shining. Then, scientists began to think that gravity was causing the sun to slowly shrink. They thought that perhaps gravity would release enough energy to heat the sun. While the release of gravitational energy is more powerful than burning, it is not enough to power the sun. If all of the sun's gravitational energy were released, the sun would last for only 45 million years. However, fossils that have been discovered prove that dinosaurs roamed the Earth more than 65 million years ago, so this couldn't be the case. Therefore, something even more powerful than gravity was needed.

Reading Check **Why isn't energy from gravity enough to power the sun?** (*See the Appendix for answers to Reading Checks.*)

Copyright © by Holt, Rinehart and Winston. All rights reserved.



CONNECTION TO Chemistry

Atoms An atom consists of a nucleus surrounded by one or more electrons. Electrons have a negative charge. In most elements, the atom's nucleus is made up of two types of particles: *protons,* which have a positive charge, and *neutrons,* which have no charge. The protons in the nucleus are usually balanced by an equal number of electrons. The number of protons and electrons gives the atom its chemical identity. A helium atom, shown at left, has two protons, two neutrons, and two electrons. Use a Periodic Table to find the chemical identity of the following atoms: nitrogen, oxygen, and carbon.

Nuclear Fusion

At the beginning of the 20th century, Albert Einstein showed that matter and energy are interchangeable. Matter can change into energy according to his famous formula: $E = mc^2$. (E is energy, m is mass, and c is the speed of light.) Because c is such a large number, tiny amounts of matter can produce a huge amount of energy. With this idea, scientists began to understand a very powerful source of energy.

nuclear fusion the combination of the nuclei of small atoms to form a larger nucleus; releases energy

Nuclear fusion is the process by which two or more low-mass nuclei join together, or fuse, to form another nucleus. In this way, four hydrogen nuclei can fuse to form a single nucleus of helium. During the process, energy is produced. Scientists now know that the sun gets its energy from nuclear fusion. Einstein's equation, shown in **Figure 3,** changed ideas about the sun's energy source by equating mass and energy.

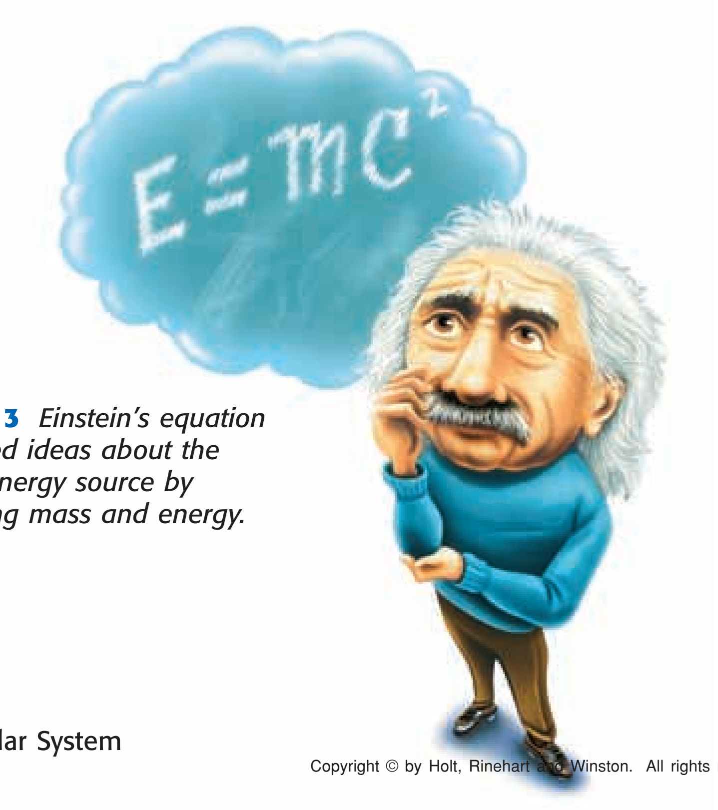


Figure 3 *Einstein's equation changed ideas about the sun's energy source by equating mass and energy.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Fusion in the Sun

During fusion, under normal conditions, the nuclei of hydrogen atoms never get close enough to combine. The reason is that they are positively charged. Like charges repel each other, as shown in **Figure 4.** In the center of the sun, however, the temperature and pressure are very high. As a result, the hydrogen nuclei have enough energy to overcome the repulsive force, and hydrogen fuses into helium, as shown in **Figure 5.**

The energy produced in the center, or core of the sun takes millions of years to reach the sun's surface. The energy passes from the core through a very dense region called the *radiative zone*. The matter in the radiative zone is so crowded that the light and energy are blocked and sent in different directions. Eventually, the energy reaches the *convective zone*. Gases circulate in the convective zone, which is about 200,000 km thick. Hot gases in the convective zone carry the energy up to the *photosphere,* the visible surface of the sun. From there, the energy leaves the sun as light, which takes only 8.3 min to reach Earth.

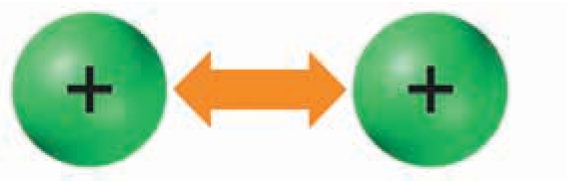
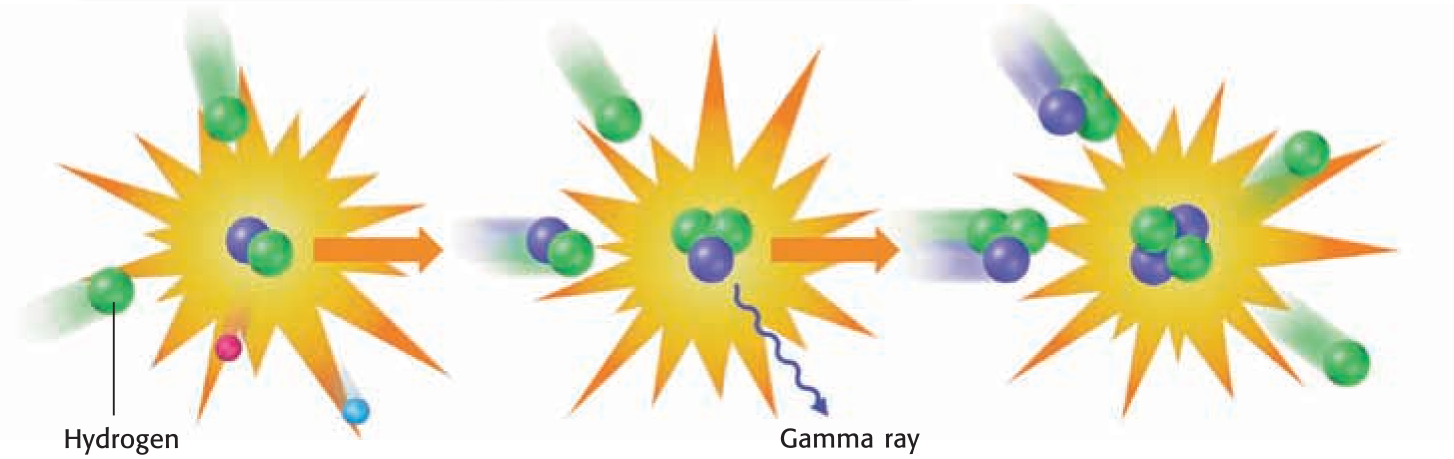


Figure 4 *Like charges repel just as similar poles on a pair of magnets do.*

Reading Check **What causes the nuclei of hydrogen atoms to repel each other?**

Figure 5 Fusion of Hydrogen in the Sun

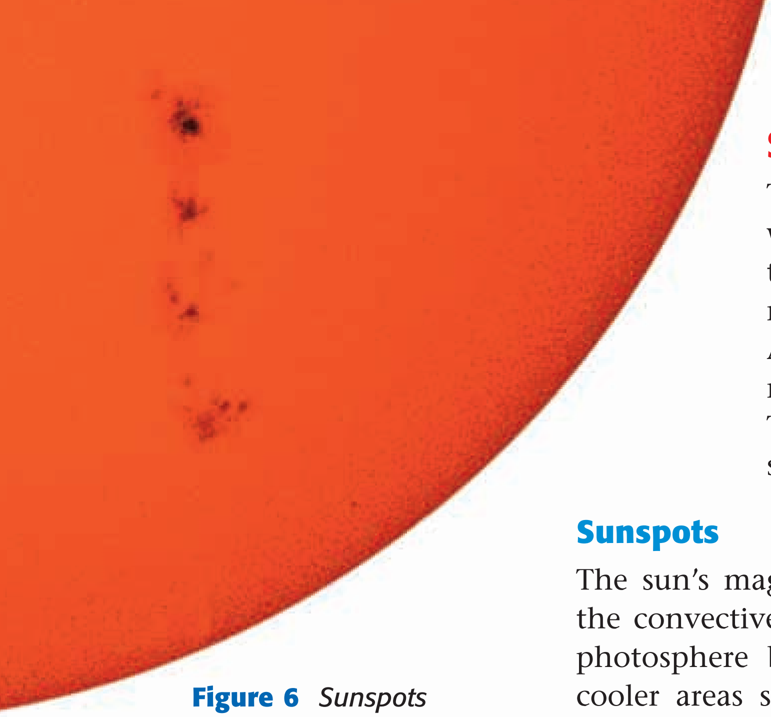


1 Deuterium Two hydrogen nuclei (protons) collide. One proton emits particles and energy and then becomes a neutron. The proton and neutron combine to produce a heavy form of hydrogen called *deuterium*.

2 Helium-3 Deuterium combines with another hydrogen nucleus to form a variety of helium called *helium-3*. More energy, as well as gamma rays, is released.

3 Helium-4 Two helium-3 atoms then combine to form ordinary helium-4, which releases more energy and a pair of hydrogen nuclei.

Copyright © by Holt, Rinehart and Winston. All rights reserved.



Solar Activity

The churning of hot gases in the sun, combined with the sun's rotation, creates magnetic fields that reach far out into space. The constant flow of magnetic fields from the sun is called *solar wind*. At times, solar wind interferes with Earth's magnetic field. This type of *solar storm* can disrupt TV signals and damage satellites. Other types of solar activity are sunspots and solar flares.

Figure 6 *Sunspots mark cooler areas on the sun's surface. They are related to changes in the magnetic properties of the sun.*

Sunspots

The sun's magnetic fields tend to slow down the activity in the convective zone. When activity slows down, areas of the photosphere become cooler than surrounding areas. These cooler areas show up as sunspots. **Sunspots** are cooler, dark spots of the photosphere of the sun, as shown in **Figure 6.** Some sunspots can be as large as 50,000 miles in diameter.

The numbers and locations of sunspots on the sun change in a regular cycle. Scientists have found that the sunspot cycle lasts about 11 years. Every 11 years, the amount of sunspot activity in the sun reaches a peak intensity and then decreases. **Figure 7** shows the sunspot cycle since 1610, excluding the years 1645–1715, which was a period of unusually low sunspot activity.

sunspot a dark area of the photosphere of the sun that is cooler than the surrounding areas and that has a strong magnetic field

Reading Check **What are sunspots? What causes sunspots to occur?**

Climate Confusion

Scientists have found that sunspot activity can affect the Earth. For example, some scientists have linked the period of low sunspot activity, 1645–1715, with the very low temperatures that Europe experienced during that time. This period is known as the "Little Ice Age." Most scientists, however, think that more research is needed to fully understand the possible connection between sunspots and Earth's climate.

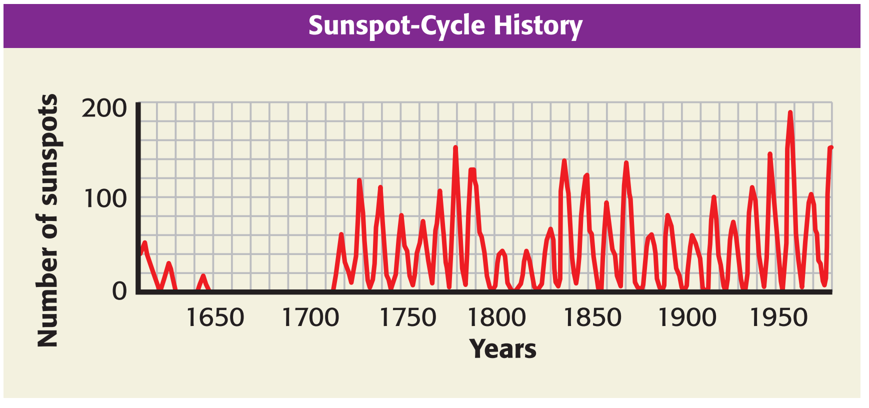


Figure 7 *This graph shows the number of sunspots that have occurred each year since Galileo's first observation in 1610.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Solar Flares

The magnetic fields that cause sunspots also cause solar flares. *Solar flares,* as shown in **Figure 8,** are regions of extremely high temperature and brightness that develop on the sun's surface. When a solar flare erupts, it sends huge streams of electrically charged particles into the solar system. Solar flares can extend upward several thousand kilometers within minutes. Solar flares are usually associated with sunspots and can interrupt radio communications on Earth and in orbit. Scientists are trying to find ways to give advance warning of solar flares.

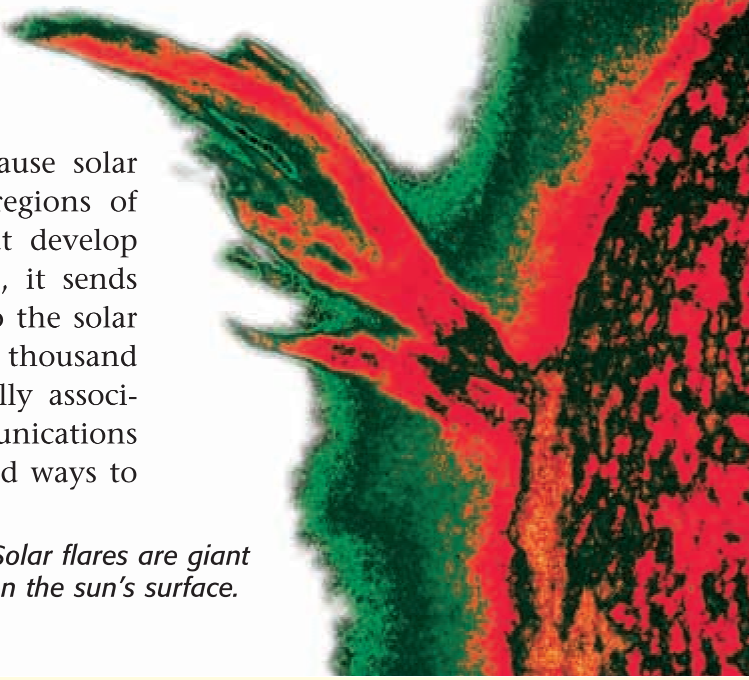


Figure 8 *Solar flares are giant eruptions on the sun's surface.*

SECTION Review

Summary

- The sun is a large ball of gas made mostly of hydrogen and helium. The sun consists of many layers.
- The sun's energy comes from nuclear fusion that takes place in the center of the sun.
- The visible surface of the sun, or the photosphere, is very active.
- Sunspots and solar flares are the result of the sun's magnetic fields that reach space.
- Sunspot activity may affect Earth's climate, and solar flares can interact with Earth's atmosphere.

Using Key Terms

1. In your own words, write a definition for each of the following terms: *sunspot* and *nuclear fusion.*

Understanding Key Ideas

2. Which of the following statements describes how energy is produced in the sun?

- **a.** The sun burns fuels to generate energy.
- **b.** As hydrogen changes into helium deep inside the sun, a great deal of energy is made.
- **c.** Energy is released as the sun shrinks because of gravity.
- **d.** None of the above

3. Describe the composition of the sun.

4. Name and describe the layers of the sun.

5. In which area of the sun do sunspots appear?

6. Explain how sunspots form.

7. Describe how sunspots can affect the Earth.

8. What are solar flares, and how do they form?

Math Skills

9. If the equatorial diameter of the sun is 1.39 million kilometers, how many kilometers is the sun's radius?

Critical Thinking

10. Applying Concepts If nuclear fusion in the sun's core suddenly stopped today, would the sky be dark in the daytime tomorrow? Explain.

11. Making Comparisons Compare the theories that scientists proposed about the source of the sun's energy with the process of nuclear fusion in the sun.

SCILINKS® NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: The Sun

SciLinks code: HSM1477

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 4

The Earth Takes Shape

In many ways, Earth seems to be a perfect place for life.

READING WARM-UP

Objectives

- Describe the formation of the solid Earth.
- Describe the structure of the Earth.
- Explain the development of Earth's atmosphere and the influence of early life on the atmosphere.
- Describe how the Earth's oceans and continents formed.

Terms to Learn

crust
mantle
core

READING STRATEGY

Discussion Read this section silently. Write down questions that you have about this section. Discuss your questions in a small group.

We live on the third planet from the sun. The Earth, shown in **Figure 1,** is mostly made of rock, and nearly three-fourths of its surface is covered with water. It is surrounded by a protective atmosphere of mostly nitrogen and oxygen and smaller amounts of other gases. But Earth has not always been such an oasis in the solar system.

Formation of the Solid Earth

The Earth formed as planetesimals in the solar system collided and combined. From what scientists can tell, the Earth formed within the first 10 million years of the collapse of the solar nebula!

The Effects of Gravity

When a young planet is still small, it can have an irregular shape, somewhat like a potato. But as the planet gains more matter, the force of gravity increases. When a rocky planet, such as Earth, reaches a diameter of about 350 km, the force of gravity becomes greater than the strength of the rock. As the Earth grew to this size, the rock at its center was crushed by gravity and the planet started to become round.

The Effects of Heat

As the Earth was changing shape, it was also heating up. Planetesimals continued to collide with the Earth, and the energy of their motion heated the planet. Radioactive material, which was present in the Earth as it formed, also heated the young planet. After Earth reached a certain size, the temperature rose faster than the interior could cool, and the rocky material inside began to melt. Today, the Earth is still cooling from the energy that was generated when it formed. Volcanoes, earthquakes, and hot springs are effects of this energy trapped inside the Earth. As you will learn later, the effects of heat and gravity also helped form the Earth's layers when the Earth was very young.

Reading Check **What factors heated the Earth during its early formation?** (*See the Appendix for answers to Reading Checks.*)

Figure 1 *When Earth is seen from space, one of its unique features—the presence of water—is apparent.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

How the Earth's Layers Formed

Have you ever watched the oil separate from vinegar in a bottle of salad dressing? The vinegar sinks because it is denser than oil. The Earth's layers formed in much the same way. As rocks melted, denser materials, such as nickel and iron, sank to the center of the Earth and formed the core. Less dense materials floated to the surface and became the crust. This process is shown in **Figure 2.**

The **crust** is the thin, outermost layer of the Earth. It is 5 to 100 km thick. Crustal rock is made of materials that have low densities, such as oxygen, silicon, and aluminum. The **mantle** is the layer of Earth beneath the crust. It extends 2,900 km below the surface. Mantle rock is made of materials such as magnesium and iron and is denser than crustal rock. The **core** is the central part of the Earth below the mantle. It contains the densest materials (nickel and iron) and extends to the center of the Earth—almost 6,400 km below the surface.

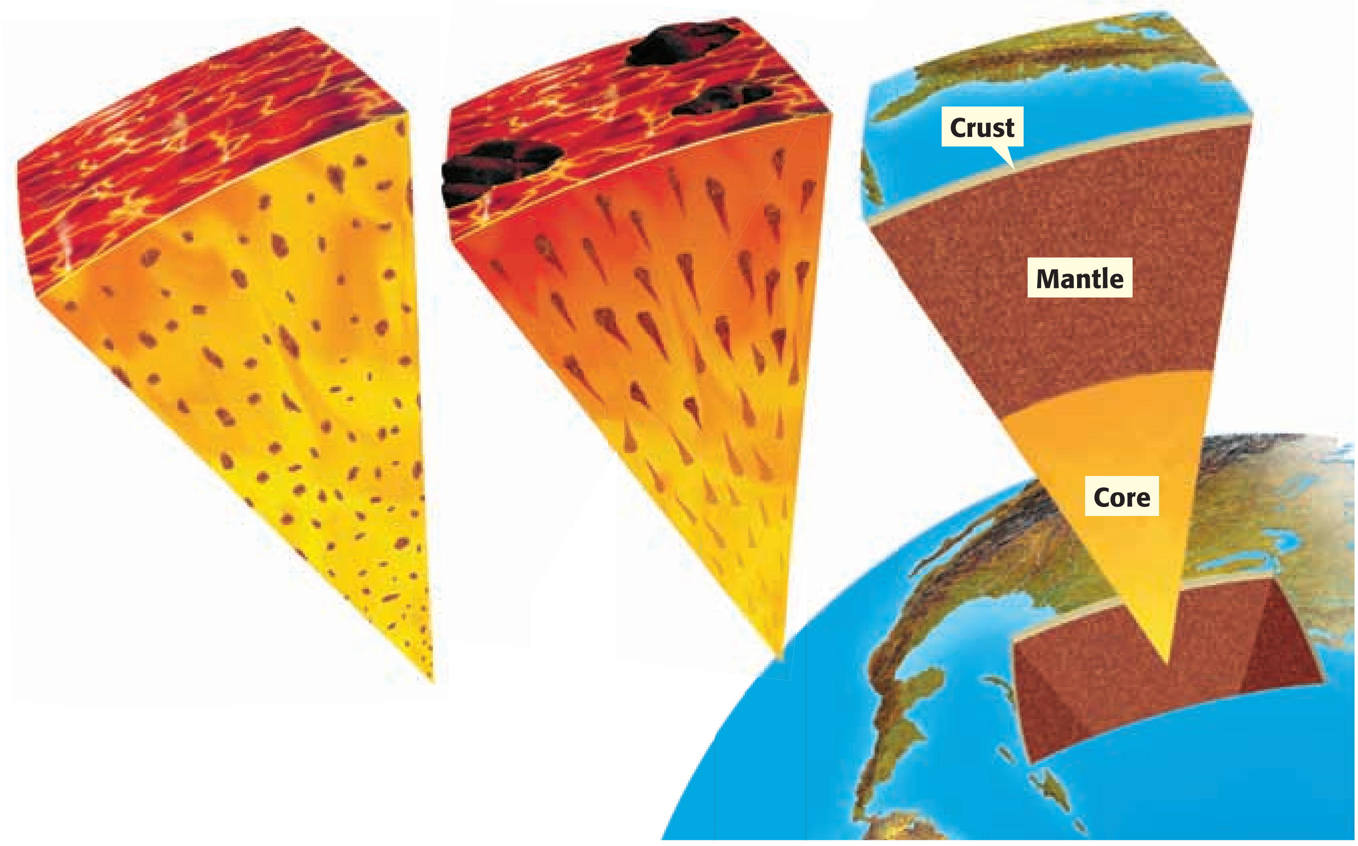
crust the thin and solid outermost layer of the Earth above the mantle

mantle the layer of rock between the Earth's crust and core

core the central part of the Earth below the mantle

Figure 2 **The Formation of Earth's Layers**

1. All materials in the early Earth are randomly mixed.
2. Rocks melt, and denser materials sink toward the center. Less dense elements rise and form layers.
3. According to composition, the Earth is divided into three layers: the crust, the mantle, and the core.



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Formation of the Earth's Atmosphere

Today, Earth's atmosphere is 78% nitrogen, 21% oxygen, and about 1% argon. (There are tiny amounts of many other gases.) Did you know that the Earth's atmosphere did not always contain the oxygen that you need to live? The Earth's atmosphere is constantly changing. Scientists think that the Earth's earliest atmosphere was very different than it is today.

Earth's Early Atmosphere

Scientists think that Earth's early atmosphere was a mixture of gases that were released as Earth cooled. During the final stages of the Earth's formation, its surface was very hot—even molten in places—as shown in **Figure 3.** The molten rock released large amounts of carbon dioxide and water vapor. Therefore, scientists think that Earth's early atmosphere was a steamy mixture of carbon dioxide and water vapor.

Reading Check **Describe Earth's early atmosphere.**

CONNECTION TO Environmental Science

WRITING SKILL **The Greenhouse Effect** Carbon dioxide is a greenhouse gas. Greenhouse gases are gases that absorb thermal energy and radiate it back to Earth. This process is called the greenhouse effect because the gases function like the walls and roof of a greenhouse, which allow solar energy to enter but prevent thermal energy from escaping. Do research to find the percentage of carbon dioxide that is thought to make up Earth's early atmosphere. Write a report, and share your findings with your class.

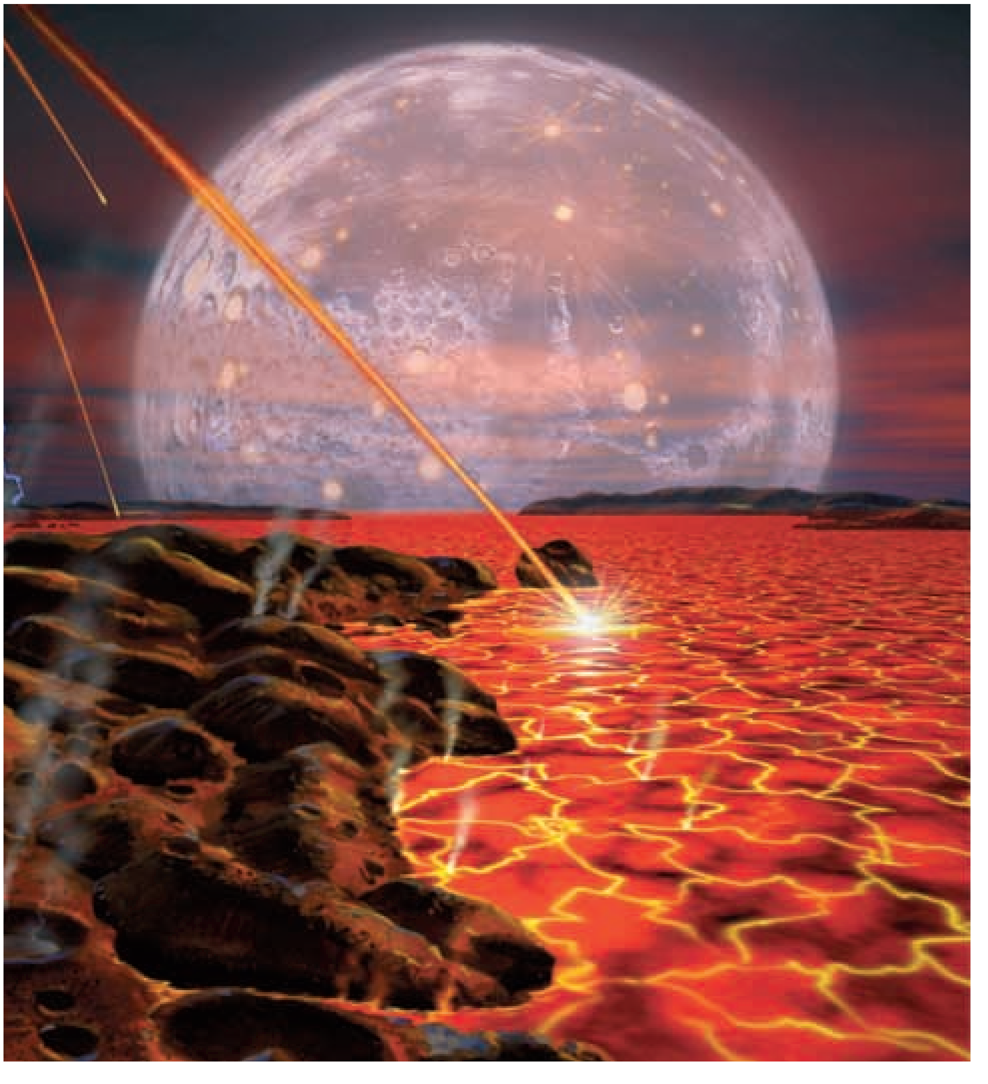


Figure 3 *This artwork is an artist's view of what Earth's surface may have looked like shortly after the Earth formed.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 4 *As this volcano in Hawaii shows, a large amount of gas is released during an eruption.*

Earth's Changing Atmosphere

As the Earth cooled and its layers formed, the Earth's atmosphere changed again. This atmosphere probably formed from volcanic gases. Volcanoes, such as the one in **Figure 4,** released chlorine, nitrogen, and sulfur in addition to large amounts of carbon dioxide and water vapor. Some of this water vapor may have condensed to form the Earth's first oceans.

Comets, which are planetesimals made of ice, also may have contributed to this change of Earth's atmosphere. As comets crashed into the Earth, they brought in a range of elements, such as carbon, hydrogen, oxygen, and nitrogen. Comets also may have brought some of the water that helped form the oceans.

The Role of Life

How did this change of Earth's atmosphere become the air you are breathing right now? The answer is related to the appearance of life on Earth.

Ultraviolet Radiation

Scientists think that ultraviolet (UV) radiation, the same radiation that causes sunburns, helped produce the conditions necessary for life. Because UV light has a lot of energy, it can break apart molecules in your skin and in the air. Today, we are shielded from most of the sun's UV rays by Earth's protective ozone layer. But Earth's early atmosphere probably did not have ozone, so many molecules in the air and at Earth's surface were broken apart. Over time, this material collected in the Earth's waters. Water offered protection from the effects of UV radiation. In these sheltered pools of water, chemicals may have combined to form the complex molecules that made life possible. The first life-forms were very simple and did not need oxygen to live.

SCHOOL to HOME

Comets and Meteors

What is the difference between a comet and a meteor? With a parent, research the difference between comets and meteors. Then, find out if you can view meteor showers in your area!

ACTIVITY

Copyright © by Holt, Rinehart and Winston. All rights reserved.

The Source of Oxygen

Sometime before 3.4 billion years ago, organisms that produced food by photosynthesis appeared. *Photosynthesis* is the process of absorbing energy from the sun and carbon dioxide from the atmosphere to make food. During the process of making food, these organisms released oxygen—a gas that was not abundant in the atmosphere at that time. Scientists think that the descendants of these early life-forms are still around today, as shown in **Figure 5.**

Photosynthetic organisms played a major role in changing Earth's atmosphere to become the mixture of gases you breathe today. Over the next hundreds of millions of years, more and more oxygen was added to the atmosphere. At the same time, carbon dioxide was removed. As oxygen levels increased, some of the oxygen formed a layer of ozone in the upper atmosphere. This ozone blocked most of the UV radiation and made it possible for life, in the form of simple plants, to move onto land about 2.2 billion years ago.

Reading Check **How did photosynthesis contribute to Earth's current atmosphere?**

Formation of Oceans and Continents

Scientists think that the oceans probably formed during Earth's second atmosphere, when the Earth was cool enough for rain to fall and remain on the surface. After millions of years of rainfall, water began to cover the Earth. By 4 billion years ago, a global ocean covered the planet.

For the first few hundred million years of Earth's history, there may not have been any continents. Given the composition of the rocks that make up the continents, scientists know that these rocks have melted and cooled many times in the past. Each time the rocks melted, the heavier elements sank and the lighter ones rose to the surface.

Figure 5 *Stromatolites, mats of fossilized algae (left), are among the earliest evidence of life. Blue-green algae (right) living today are thought to be similar to the first life-forms on Earth.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

The Growth of Continents

After a while, some of the rocks were light enough to pile up on the surface. These rocks were the beginning of the earliest continents. The continents gradually thickened and slowly rose above the surface of the ocean. These scattered young continents did not stay in the same place, however. The slow transfer of thermal energy in the mantle pushed them around. Approximately 2.5 billion years ago, continents really started to grow. And by 1.5 billion years ago, the upper mantle had cooled and had become denser and heavier. At this time, it was easier for the cooler parts of the mantle to sink. These conditions made it easier for the continents to move in the same way that they do today.

INTERNET ACTIVITY

For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HZ5SOLW.**

SECTION Review

Summary

- The effects of gravity and heat created the shape and structure of Earth.
- The Earth is divided into three main layers based on composition: the crust, mantle, and core.
- The presence of life dramatically changed Earth's atmosphere by adding free oxygen.
- Earth's oceans formed shortly after the Earth did, when it had cooled off enough for rain to fall. Continents formed when lighter materials gathered on the surface and rose above sea level.

Using Key Terms

1. Use each of the following terms in a separate sentence: *crust*, *mantle*, and *core*.

Understanding Key Ideas

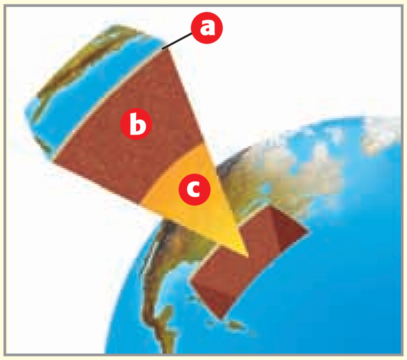
2. Earth's first atmosphere was mostly made of
   a. nitrogen and oxygen.
   b. chlorine, nitrogen, and sulfur.
   c. carbon dioxide and water vapor.
   d. water vapor and oxygen.
3. Describe the structure of the Earth.
4. Why did the Earth separate into distinct layers?
5. Describe the development of Earth's atmosphere. How did life affect Earth's atmosphere?
6. Explain how Earth's oceans and continents formed.

Critical Thinking

7. **Applying Concepts** How did the effects of gravity help shape the Earth?
8. **Making Inferences** How would the removal of forests affect the Earth's atmosphere?

Interpreting Graphics

Use the illustration below to answer the questions that follow.



9. Which of the layers is composed mostly of the elements magnesium and iron?
10. Which of the layers is composed mostly of the elements iron and nickel?

SCILINKS NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: The Layers of the Earth; The Oceans
SciLinks code: HSM0862; HSM1069

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Using Scientific Methods

Skills Practice Lab

How Far Is the Sun?

It doesn't slice, it doesn't dice, but it can give you an idea of how big our universe is! You can build your very own solar-distance measuring device from household items. Amaze your friends by figuring out how many metersticks can be placed between the Earth and the sun.

OBJECTIVES

Create a solar-distance measuring device.

Calculate the Earth's distance from the sun.

MATERIALS

- aluminum foil, 5 cm × 5 cm
- card, index
- meterstick
- poster board
- ruler, metric
- scissors
- tape, masking
- thumbtack

SAFETY

Ask a Question

1. How many metersticks could I place between the Earth and the sun?

Form a Hypothesis

2. Write a hypothesis that answers the question above.

Test the Hypothesis

3. Measure and cut a 4 cm × 4 cm square from the middle of the poster board. Tape the foil square over the hole in the center of the poster board.
4. Using a thumbtack, carefully prick the foil to form a tiny hole in the center. Congratulations! You have just constructed your very own solar-distance measuring device!
5. Tape the device to a window facing the sun so that sunlight shines directly through the pinhole. **Caution:** Do not look directly into the sun.
6. Place one end of the meterstick against the window and beneath the foil square. Steady the meterstick with one hand.
7. With the other hand, hold the index card close to the pinhole. You should be able to see a circular image on the card. This image is an image of the sun.
8. Move the card back until the image is large enough to measure. Be sure to keep the image on the card sharply focused. Reposition the meterstick so that it touches the bottom of the card.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

9. Ask your partner to measure the diameter of the image on the card by using the metric ruler. Record the diameter of the image in millimeters.

10. Record the distance between the window and the index card by reading the point at which the card rests on the meterstick.

11. Calculate the distance between Earth and the sun by using the following formula:

$$\textit{distance between the sun and Earth} = \textit{sun's diameter} \times \frac{\textit{distance to the image}}{\textit{image's diameter}}$$

(Hint: The sun's diameter is 1,392,000,000 m.)

1 cm = 10 mm
1 m = 100 cm
1 km = 1,000 m

Analyze the Results

1. **Analyzing Results** According to your calculations, how far from the Earth is the sun? Don't forget to convert your measurements to meters.

Draw Conclusions

2. **Evaluating Data** You could put 150 billion metersticks between the Earth and the sun. Compare this information with your result in step 11. Do you think that this activity was a good way to measure the Earth's distance from the sun? Support your answer.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Chapter Review

USING KEY TERMS

Complete each of the following sentences by choosing the correct term from the word bank.

nebula	crust
mantle	solar nebula

1. A ___ is a large cloud of gas and dust in interstellar space.

2. The ___ lies between the core and the crust of the Earth.

For each pair of terms, explain how the meanings of the terms differ.

3. *nebula* and *solar nebula*

4. *crust* and *mantle*

5. *globular cluster* and *galaxy*

6. *nuclear fusion* and *sunspot*

UNDERSTANDING KEY IDEAS

Multiple Choice

7. Scientists use which unit of length to measure distance in space?
   - **a.** kilometers
   - **b.** miles
   - **c.** light-years
   - **d.** None of the above

8. During Earth's formation, materials such as nickel and iron sank to the
   - **a.** mantle.
   - **b.** core.
   - **c.** crust.
   - **d.** All of the above

9. Galaxies that have very bright centers and very little dust and gas are called
   - **a.** irregular galaxies.
   - **b.** spiral galaxies.
   - **c.** elliptical galaxies.
   - **d.** None of the above

10. Impacts in the early solar system
    - **a.** brought new materials to the planets.
    - **b.** released energy.
    - **c.** dug craters.
    - **d.** All of the above

11. Organisms that photosynthesize get their energy from
    - **a.** nitrogen.
    - **b.** oxygen.
    - **c.** the sun.
    - **d.** water.

12. Starlike sources of light that are extremely far away are called
    - **a.** galaxies.
    - **b.** nebulas.
    - **c.** quasars.
    - **d.** clusters.

13. Which gas in Earth's atmosphere suggests that there is life on Earth?
    - **a.** hydrogen
    - **b.** oxygen
    - **c.** carbon dioxide
    - **d.** nitrogen

14. Which layer of the Earth has the lowest density?
    - **a.** the core
    - **b.** the mantle
    - **c.** the crust
    - **d.** None of the above

15. What is the measure of the average kinetic energy of particles in an object?
    - **a.** temperature
    - **b.** pressure
    - **c.** gravity
    - **d.** force

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Short Answer

16 Compare a sunspot with a solar flare.

17 Describe how the Earth's oceans and continents formed.

18 Explain how pressure and gravity may have become unbalanced in the solar nebula.

19 Define *nuclear fusion* in your own words. Describe how nuclear fusion generates the sun's energy.

CRITICAL THINKING

20 **Concept Mapping** Use the following terms to create a concept map: *solar nebula, solar system, planetesimals, sun, photosphere, core, nuclear fusion, planets,* and *Earth.*

21 **Making Comparisons** Which contains more stars on average, a globular cluster or an open cluster?

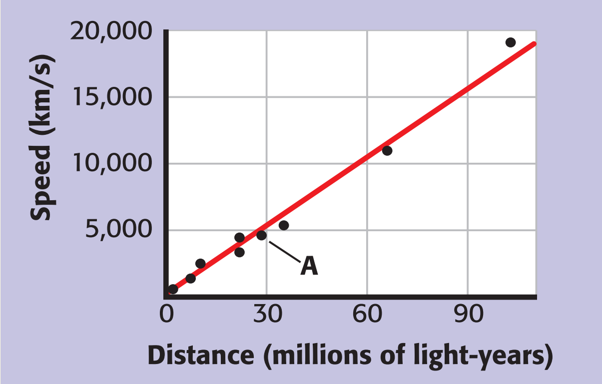
22 **Predicting Consequences** Using what you know about the relationship between living things and the development of Earth's atmosphere, explain how the formation of ozone holes in Earth's atmosphere could affect living things.

23 **Identifying Relationships** Imagine you visited an observatory and looked through the telescope. You saw a ball of stars through the telescope. What type of object did you see?

INTERPRETING GRAPHICS

The graph below shows Hubble's law, which relates how far galaxies are from Earth and how fast they are moving away from Earth. Use the graph below to answer the questions that follow.

Galaxy Speed Vs. Distance

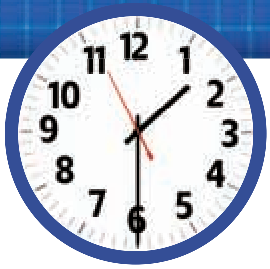


24 Look at the point that represents galaxy A in the graph. How far is galaxy A from Earth, and how fast is it moving away from Earth?

25 If a galaxy is moving away from Earth at 15,000 km/s, how far is the galaxy from Earth?

26 If a galaxy is 90,000,000 light-years from Earth, how fast is it moving away from Earth?

Copyright © by Holt, Rinehart and Winston. All rights reserved.



Standardized Test Preparation

EOG Prep

READING

Read each of the passages below. Then, answer the questions that follow each passage.

Passage 1 You know that you should not look at the sun, right? But how can we learn anything about the sun if we can't look at it? We can use a solar telescope! About 70 km southwest of Tucson, Arizona, is Kitt Peak National Observatory, where you will find three solar telescopes. In 1958, Kitt Peak was chosen from more than 150 mountain sites to be the site for a national observatory. Located in the Sonoran Desert, Kitt Peak is on land belonging to the Tohono O'odham Indian nation. On this site, the McMath-Pierce Facility houses the three largest solar telescopes in the world. Astronomers come from around the globe to use these telescopes. The largest of the three, the McMath-Pierce solar telescope, produces an image of the sun that is almost 1 m wide!

1. Which of the following is the largest telescope in the world?

A Kitt Peak
B Tohono O'odham
C McMath-Pierce
D Tucson

2. According to the passage, how can you learn about the sun?

F You can look at it.
G You can study it by using a solar telescope.
H You can go to Kitt Peak National Observatory.
I You can study to be an astronomer.

3. Which of the following is a fact in the passage?

A One hundred fifty mountain sites contain solar telescopes.
B Kitt Peak is the location of the smallest solar telescope in the world.
C In 1958, Tucson, Arizona, was chosen for a national observatory.
D Kitt Peak is the location of the largest solar telescope in the world.

Passage 2 Sunlight that has been focused can produce a great amount of thermal energy—enough to start a fire. Now, imagine focusing the sun's rays by using a magnifying glass that is 1.6 m in diameter. The resulting heat could melt metal. If a conventional telescope were pointed directly at the sun, it would melt. To avoid a meltdown, the McMath-Pierce solar telescope uses a mirror that produces a large image of the sun. This mirror directs the sun's rays down a diagonal shaft to another mirror, which is 50 m underground. This mirror is adjustable to focus the sunlight. The sunlight is then directed to a third mirror, which directs the light to an observing room and instrument shaft.

1. In this passage, what does the word *conventional* mean?

A special
B solar
C unusual
D ordinary

2. What can you infer from reading the passage?

F Focused sunlight can avoid a meltdown.
G Unfocused sunlight produces little energy.
H A magnifying glass can focus sunlight to produce a great amount of thermal energy.
I Mirrors increase the intensity of sunlight.

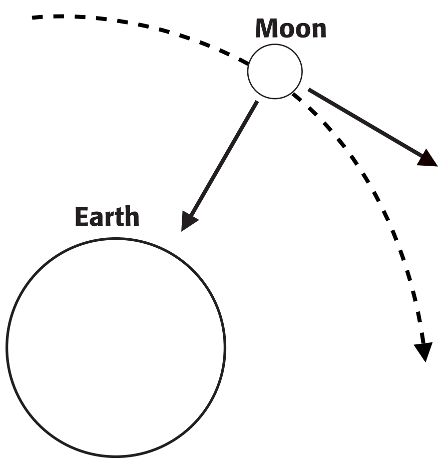
3. According to the passage, which of the following statements about solar telescopes is true?

A Solar telescopes make it safe for scientists to observe the sun.
B Solar telescopes don't need to use mirrors.
C Solar telescopes are built 50 m underground.
D Solar telescopes are 1.6 m in diameter.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

INTERPRETING GRAPHICS

The diagram below models the moon's orbit around the Earth. Use the diagram below to answer the questions that follow.



1. Which statement best describes the diagram?
   - **A** Orbits are straight lines.
   - **B** The force of gravity does not affect orbits.
   - **C** Orbits result from a combination of gravitational attraction and inertia.
   - **D** The moon moves in three different directions depending on its speed.

2. In which direction does gravity pull the moon?
   - **F** toward the Earth
   - **G** around the Earth
   - **H** away from the Earth
   - **I** toward and away from the Earth

3. If the moon stopped moving, what would happen?
   - **A** It would fly off into space.
   - **B** It would continue to orbit the Earth.
   - **C** It would stay where it is in space.
   - **D** It would move toward the Earth.

MATH

Read each question below, and choose the best answer.

1. An astronomer found 3 planetary systems in the nebula that she was studying. One system had 6 planets, another had 2 planets, and the third had 7 planets. What is the average number of planets in all 3 systems?
   - **A** 3
   - **B** 5
   - **C** 8
   - **D** 16

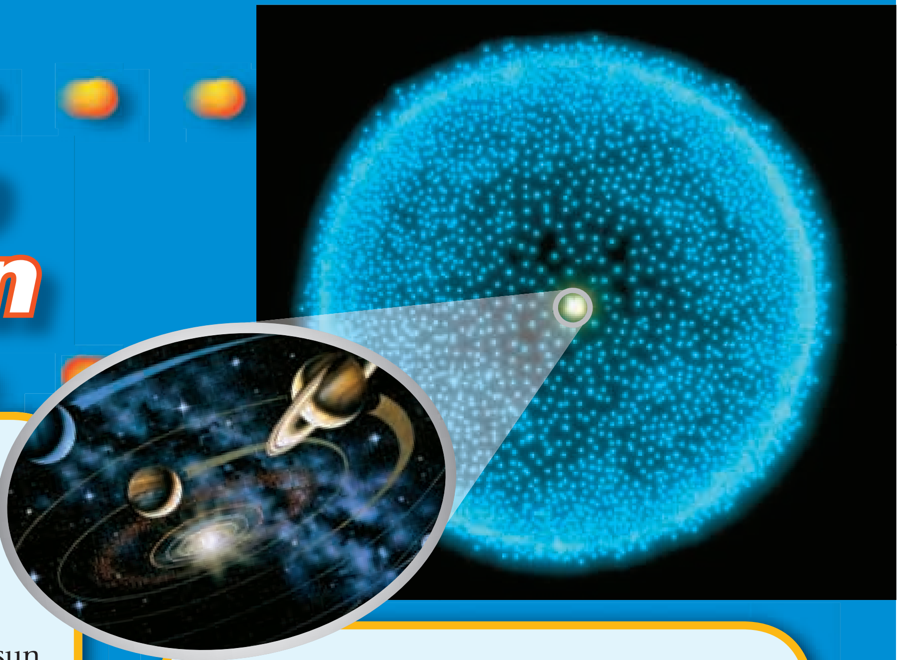
2. A newly discovered planet has a period of rotation of 270 Earth years. How many Earth days are in 270 Earth years?
   - **F** 3,240
   - **G** 8,100
   - **H** 9,855
   - **I** 98,550

3. A planet has seven rings. The first ring is 20,000 km from the center of the planet. Each ring is 50,000 km wide and 500 km apart. What is the total radius of the ring system from the planet's center?
   - **A** 353,000 km
   - **B** 373,000 km
   - **C** 373,500 km
   - **D** 370,000 km

4. If you bought a telescope for $87.75 and received a $10 bill, two $1 bills, and a quarter as change, how much money did you give the clerk?
   - **F** $100
   - **G** $99
   - **H** $98
   - **I** $90

Copyright © by Holt, Rinehart and Winston. All rights reserved.

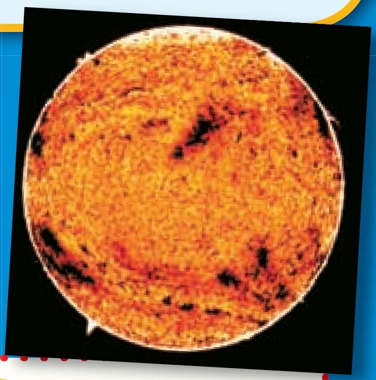
Science in Action



Science, Technology, and Society

Don't Look at the Sun!

How can we learn anything about the sun if we can't look at it? The answer is to use a special telescope called a *solar telescope*. The three largest solar telescopes in the world are located at Kitt Peak National Observatory near Tucson, Arizona. The largest of these telescopes, the McMath-Pierce solar telescope, creates an image of the sun that is almost 1 m wide! How is the image created? The McMath-Pierce solar telescope uses a mirror that is more than 2 m in diameter to direct the sun's rays down a diagonal shaft to another mirror, which is 152 m underground. This mirror is adjustable to focus the sunlight. The sunlight is then directed to a third mirror, which directs the light to an observing room and instrument shaft.



Math Activity

The outer skin of the McMath-Pierce solar telescope consists of 140 copper panels that measure 10.4 m × 2.4 m each. How many square meters of copper were used to construct the outer skin of the telescope?

Scientific Discoveries

The Oort Cloud

Have you ever wondered where comets come from? In 1950, Dutch astronomer Jan Oort decided to find out where comets originated. Oort studied 19 comets. He found that none of these comets had orbits indicating that the comets had come from outside the solar system. Oort thought that all of the comets had come from an area at the far edge of the solar system. In addition, he believed that the comets had entered the planetary system from different directions. These conclusions led Oort to theorize that the area from which comets come surrounds the solar system like a sphere and that comets can come from any point within the sphere. Today, this spherical zone at the edge of the solar system is called the *Oort Cloud*. Astronomers believe that billions or even trillions of comets may exist within the Oort Cloud.

Social Studies Activity

WRITING SKILL Before astronomers understood the nature of comets, comets were a source of much fear and misunderstanding among humans. Research some of the myths that humans have created about comets. Summarize your findings in a short essay.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

People in Science

Subrahmanyan Chandrasekhar

From White Dwarfs to Black Holes You may be familiar with the *Chandra X-Ray Observatory*. Launched by NASA in July 1999 to search for x-ray sources in space, the observatory is the most powerful x-ray telescope that has ever been built. However, you may not know how the observatory got its name. The *Chandra X-Ray Observatory* was named after the Indian American astrophysicist Subrahmanyan Chandrasekhar (SOOB ruh MAHN yuhn CHUHN druh SAY kuhr).

One of the most influential astrophysicists of the 20th century, Chandrasekhar was simply known as "Chandra" by his fellow scientists. Chandrasekhar made many contributions to physics and astrophysics. The contribution for which Chandrasekhar is best known was made in 1933, when he was a 23-year-old graduate student at Cambridge University in England. At the time, astrophysicists thought that all stars eventually became planet-sized stars known as *white dwarfs*. But from his calculations, Chandrasekhar believed that not all stars ended their lives as white dwarfs. He determined that the upper limit to the mass of a white dwarf was 1.4 times the mass of the sun. Stars that were more massive would collapse and would become very dense objects. These objects are now known as *black holes*. Chandrasekhar's ideas revolutionized astrophysics. In 1983, at the age of 73, Chandrasekhar was awarded the Nobel Prize in physics for his work on the evolution of stars.

Language Arts ACTIVITY

WRITING SKILL Using the Internet or another source, research the meaning of the word *chandra*. Write a paragraph describing your findings.

go.hrw.com

To learn more about these Science in Action topics, visit go.hrw.com and type in the keyword HZ5SOLF.

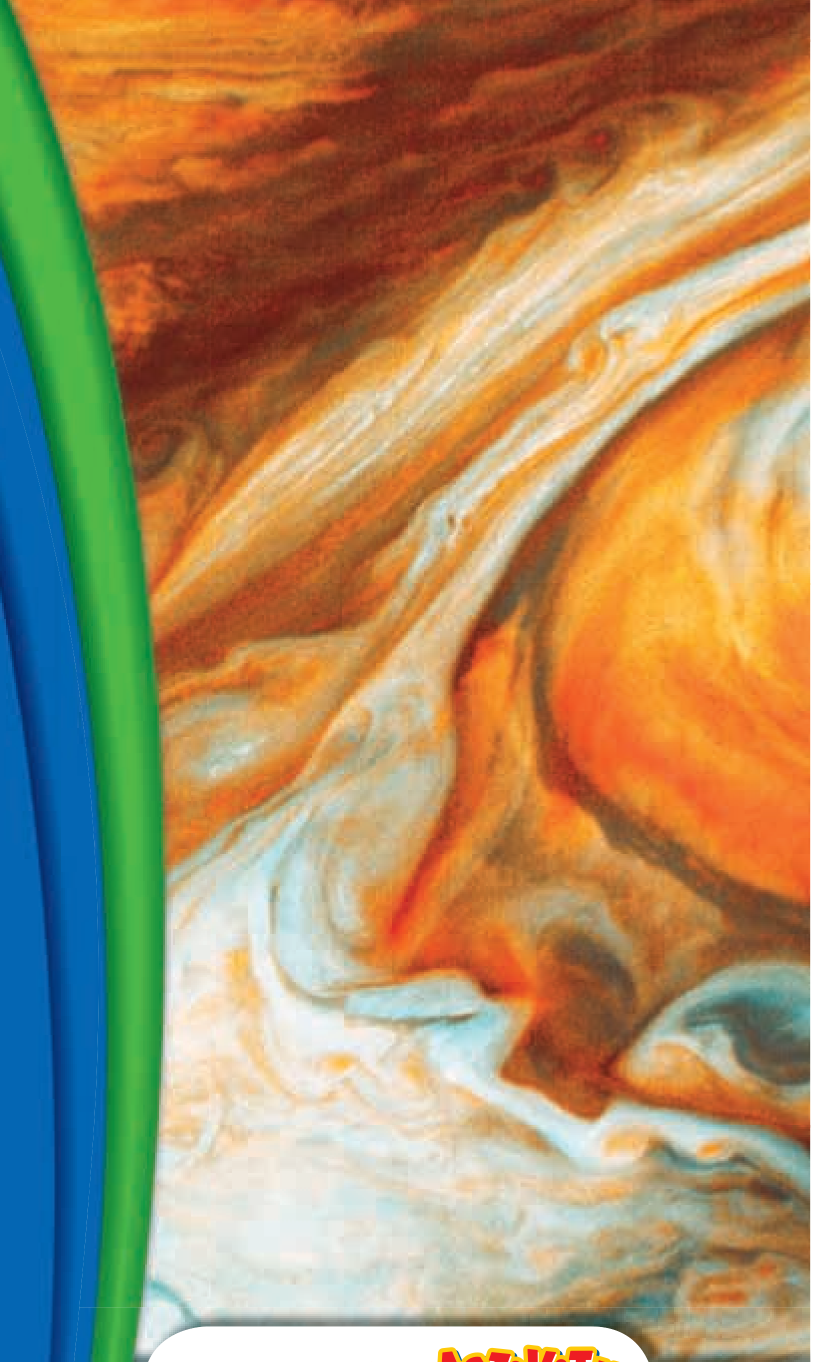
Current Science

Check out Current Science® articles related to this chapter by visiting go.hrw.com. Just type in the keyword HZ5CS20.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

11

A Family of Planets



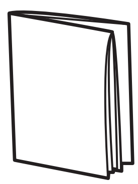
About the PHOTO

These rich swirls of color may remind you of a painting you might see in an art museum. But this photograph is of the planet Jupiter. The red swirl, called the Great Red Spot, is actually a hurricane-like storm system that is 3 times the diameter of Earth!

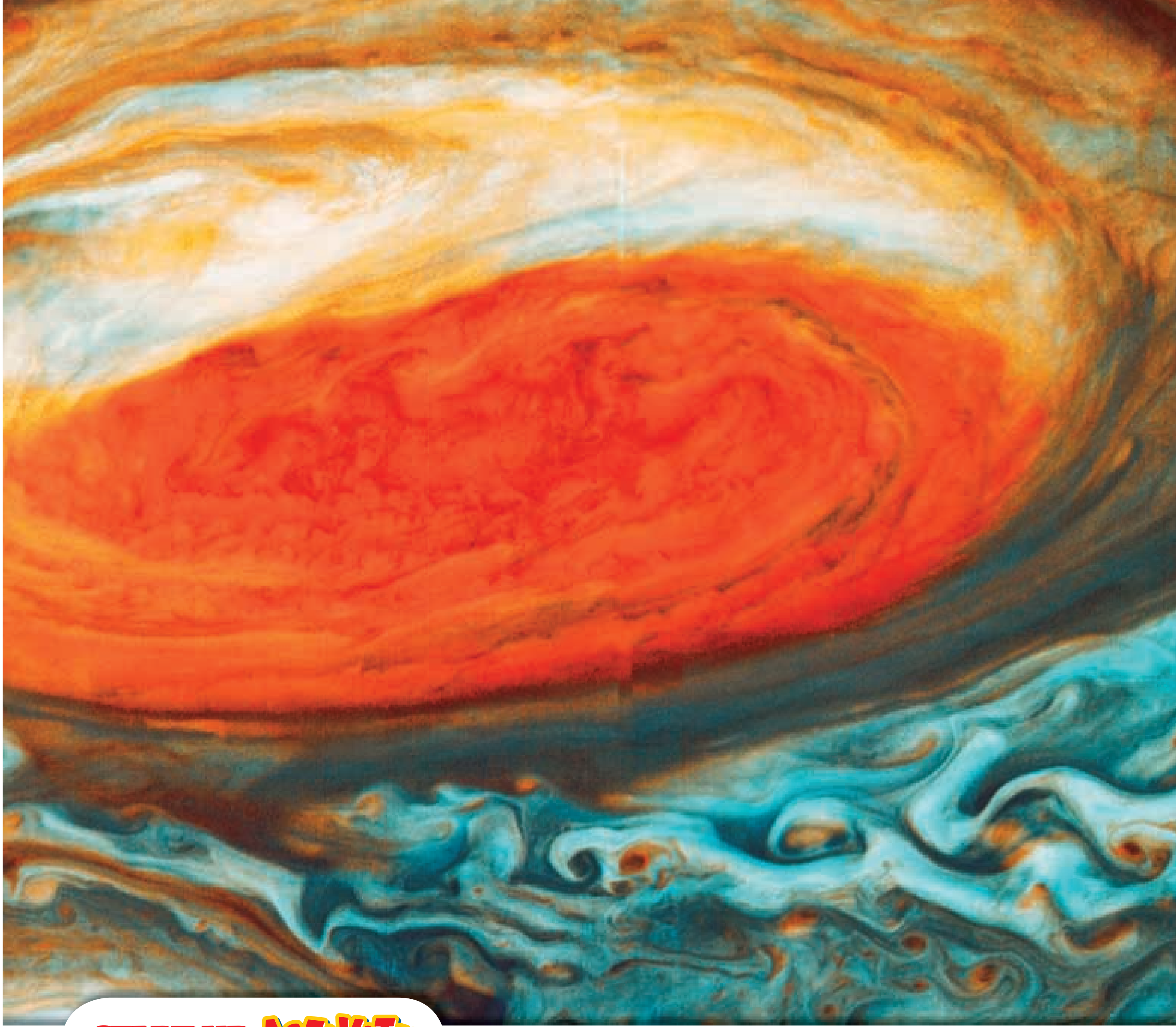
PRE-READING ACTIVITY

FOLDNOTES

Booklet Before you read the chapter, create the FoldNote entitled "Booklet" described in the **Study Skills** section of the Appendix. Label each page of the booklet with a name of a planet in our solar system. As you read the chapter, write what you learn about each planet on the appropriate page of the booklet.



Copyright © by Holt, Rinehart and Winston. All rights reserved.



START-UP ACTIVITY

Measuring Space

Do the following activity to get a better idea of your solar neighborhood.

Procedure

1. Use a **meterstick** and some **chalk** to draw a line 2 m long on a **chalkboard.** Draw a large dot at one end of the line. This dot represents the sun.
2. Draw smaller dots on the line to represent the relative distances of each of the planets from the sun, based on information in the table.

Analysis

1. What do you notice about how the planets are spaced?

Planet	Distance from sun	
	Millions of km	Scaled to cm
Mercury	57.9	2
Venus	108.2	4
Earth	149.6	5
Mars	227.9	8
Jupiter	778.4	26
Saturn	1,424.0	48
Uranus	2,827.0	97
Neptune	4,499.0	151
Pluto	5,943.0	200

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 1

The Nine Planets

Did you know that planets, when viewed from Earth, look like stars to the naked eye? Ancient astronomers were intrigued by these "stars" which seemed to wander in the sky.

Ancient astronomers named these "stars" planets, which means "wanderers" in Greek. These astronomers knew planets were physical bodies and could predict their motions. But scientists did not begin to explore these worlds until the 17th century, when Galileo used the telescope to study planets and stars. Now, scientists have completed more than 150 successful missions to moons, planets, comets, and asteroids in our cosmic neighborhood.

READING WARM-UP

Objectives

- List the planets in the order in which they orbit the sun.
- Explain how scientists measure distances in space.
- Describe how the planets in our solar system were discovered.
- Describe three ways in which the inner planets and outer planets differ.

Terms to Learn

astronomical unit

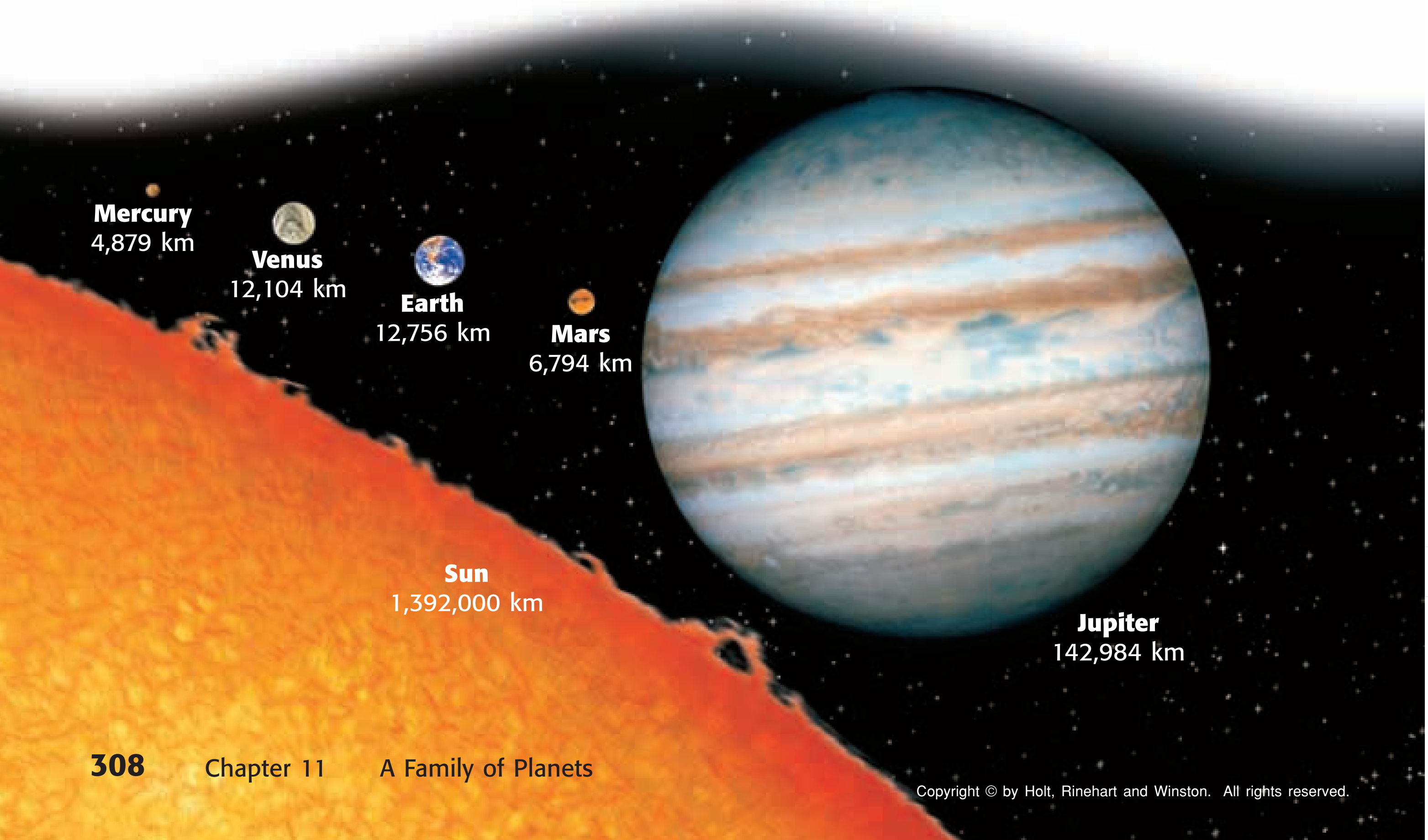
READING STRATEGY

Paired Summarizing Read this section silently. In pairs, take turns summarizing the material. Stop to discuss ideas that seem confusing.

Our Solar System

Our *solar system,* shown in **Figure 1,** includes the sun, the planets, and many smaller objects. In some cases, these bodies may be organized into smaller systems of their own. For example, the Saturn system is made of the planet Saturn and the several moons that orbit Saturn. In this way, our solar system is a combination of many smaller systems.

Figure 1 *These images show the relative diameters of the planets and the sun.*



Copyright © by Holt, Rinehart and Winston. All rights reserved.

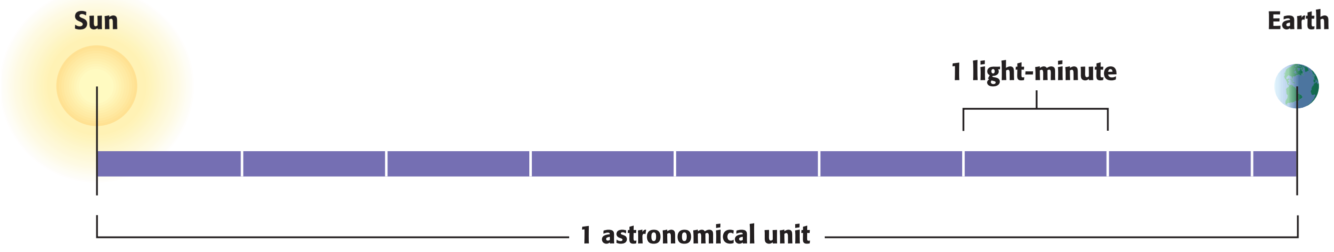


Figure 2 *One astronomical unit equals about 8.3 light-minutes.*

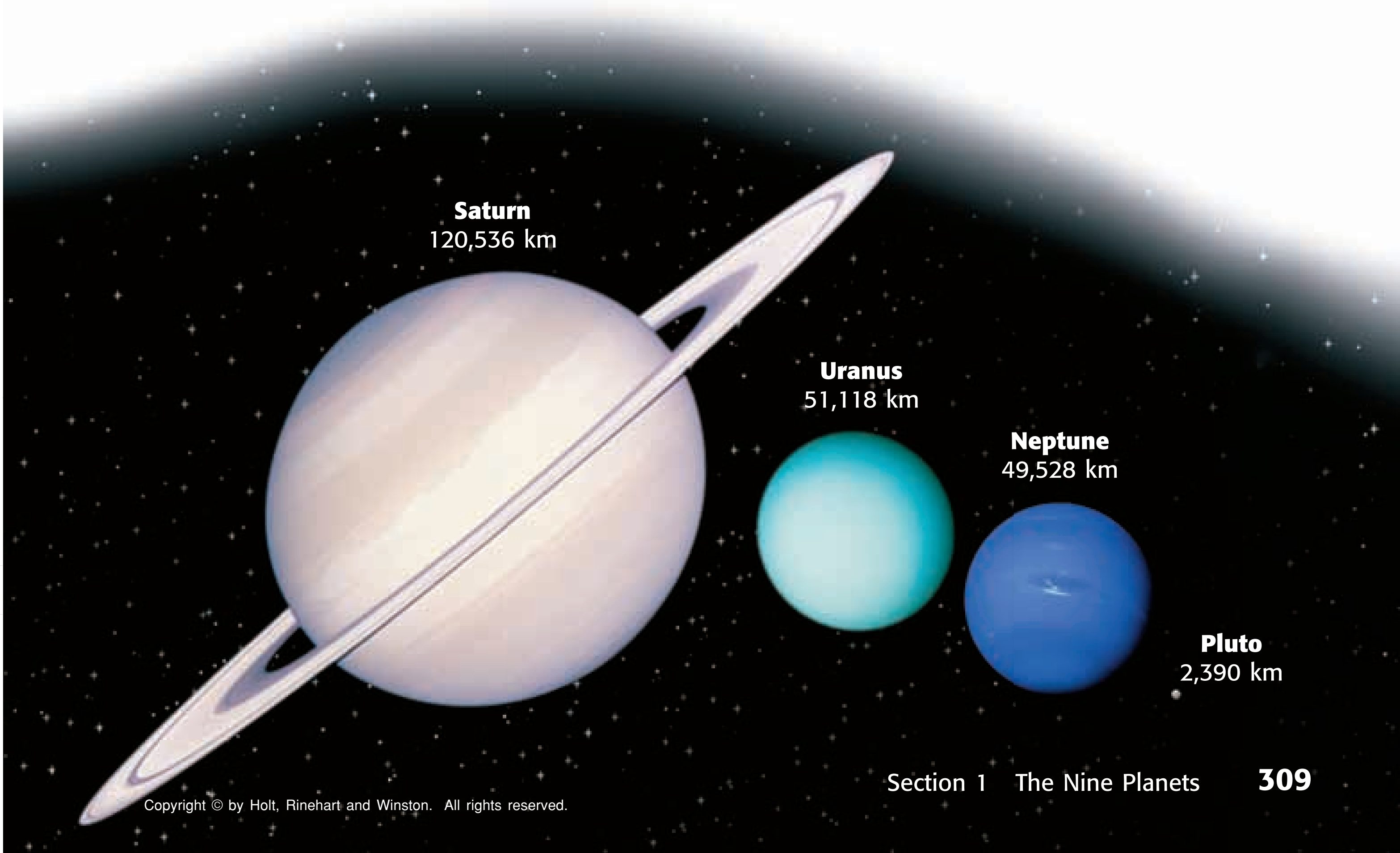
Measuring Interplanetary Distances

One way that scientists measure distances in space is by using the astronomical unit. One **astronomical unit** (AU) is the average distance between the sun and Earth, or approximately 150,000,000 km. Another way to measure distances in space is by using the speed of light. Light travels at about 300,000 km/s in space. This means that in 1 s, light travels 300,000 km.

In 1 min, light travels nearly 18,000,000 km. This distance is also called a *light-minute*. Look at **Figure 2.** Light from the sun takes 8.3 min to reach Earth. So, the distance from Earth to the sun, or 1 AU, is 8.3 light-minutes. Distances in the solar system can be measured in light-minutes and light-hours.

astronomical unit the average distance between the Earth and the sun; approximately 150 million kilometers (symbol, AU)

Reading Check **How far does light travel in 1 s?** (*See the Appendix for answers to Reading Checks.*)



Copyright © by Holt, Rinehart and Winston. All rights reserved.

The Discovery of the Solar System

Up until the 17th century, the universe was thought to have only eight bodies. These bodies included the planets Earth, Mercury, Venus, Mars, Jupiter, and Saturn, the sun, and the Earth's moon. These bodies are the only ones that can be seen from Earth without using a telescope.

After the telescope was invented in the 17th century, however, more discoveries were made. By the end of the 17th century, nine more large bodies were discovered. These bodies were moons of Jupiter and Saturn.

By the 18th century, the planet Uranus, along with two of its moons and two more of Saturn's moons, was discovered. In the 19th century, Neptune, as well as moons of several other planets, was discovered. Finally, in the 20th century, the ninth planet, Pluto, was discovered.

INTERNET ACTIVITY

For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HZ5FAMW.**

The Inner and Outer Solar Systems

The solar system is divided into two main parts: the inner solar system and the outer solar system. The inner solar system contains the four planets that are closest to the sun. The outer solar system contains the planets that are farthest from the sun.

The Inner Planets

The planets of the inner solar system, shown in **Figure 3,** are more closely spaced than the planets of the outer solar system. The inner planets are also known as the *terrestrial planets* because their surfaces are dense and rocky. However, each of the inner planets is unique.

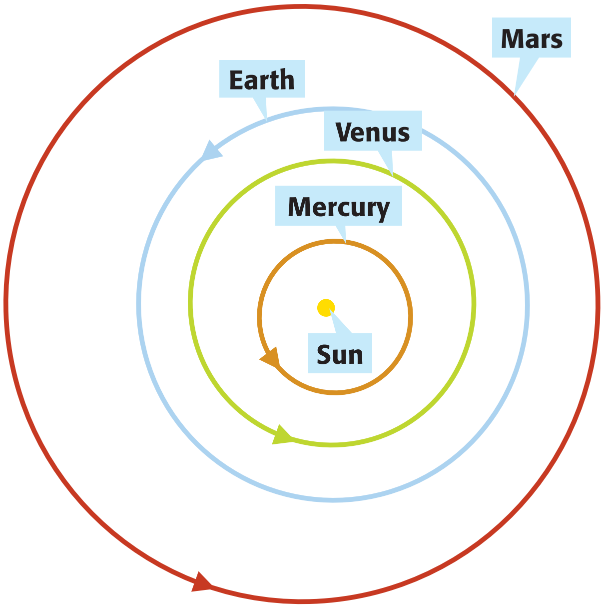


Figure 3 *The inner planets are the planets that are closest to the sun.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

The Outer Planets

The planets of the outer solar system include Jupiter, Saturn, Uranus, Neptune, and Pluto. The outer planets are very different from the inner planets, as you will soon find out.

Unlike the inner planets, the outer planets, except for Pluto, are large and are composed mostly of gases. Because of this, Jupiter, Saturn, Uranus, and Neptune are known as gas giants. The atmospheres of these planets blend smoothly into the denser layers of their interiors. The icy planet Pluto is the only planet of the outer solar system that is small, dense, and rocky. You can see a diagram of the outer solar system in **Figure 4.**

Reading Check **Which planets are in the outer solar system?**

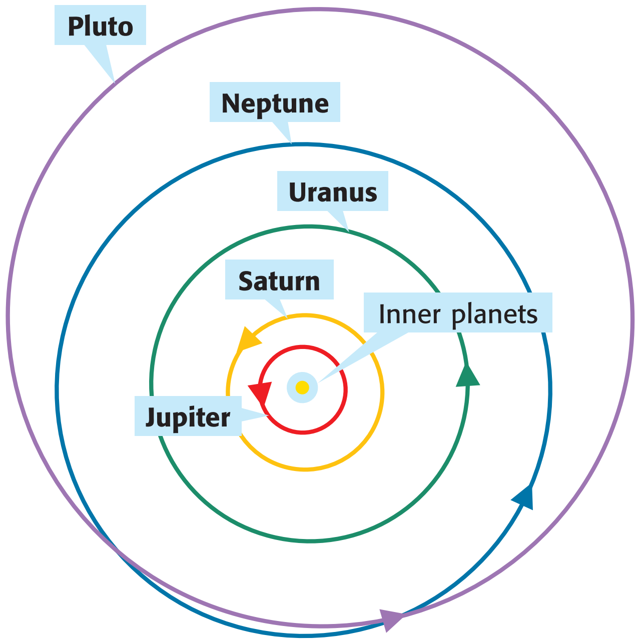


Figure 4 The planets of the outer solar system are the farthest from the sun.

SECTION Review

Summary

- In the order in which they orbit the sun, the nine planets are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto.
- Two ways in which scientists measure distances in space are to use astronomical units and to use light-years.
- The inner planets are spaced more closely together, are smaller, and are rockier than the outer planets.

Using Key Terms

1. In your own words, write a definition for the term *astronomical unit.*

Understanding Key Ideas

2. When was the planet Uranus discovered?
   a. before the 17th century
   b. in the 18th century
   c. in the 19th century
   d. in the 20th century
3. The invention of what instrument helped early scientists discover more bodies in the solar system?
4. Which of the nine planets are included in the outer solar system?
5. Describe how the inner planets are different from the outer planets.

Math Skills

6. If Venus is 6.0 light-minutes from the sun, what is Venus's distance from the sun in astronomical units?

Critical Thinking

7. **Analyzing Methods** The distance between Earth and the sun is measured in light-minutes, but the distance between Pluto and the sun is measured in light-hours. Explain why.

SCILINKS. NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: The Nine Planets
SciLinks code: HSM1033

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 2

The Inner Planets

In the inner solar system, you will find one of the hottest places in our solar system as well as the only planet known to support life.

READING WARM-UP

Objectives

- Explain the difference between a planet's period of rotation and period of revolution.
- Describe the difference between prograde and retrograde rotation.
- Describe the individual characteristics of Mercury, Venus, Earth, and Mars.
- Identify the characteristics that make Earth suitable for life.

Terms to Learn

terrestrial planet
prograde rotation
retrograde rotation

READING STRATEGY

Reading Organizer As you read this section, create an outline of the section. Use the headings from the section in your outline.

terrestrial planet one of the highly dense planets nearest to the sun; Mercury, Venus, Mars, and Earth

The inner planets are also called **terrestrial planets** because, like Earth, they are very dense and rocky. The inner planets are smaller, denser, and rockier than the outer planets. In this section, you will learn more about the individual characteristics of Mercury, Venus, Earth, and Mars.

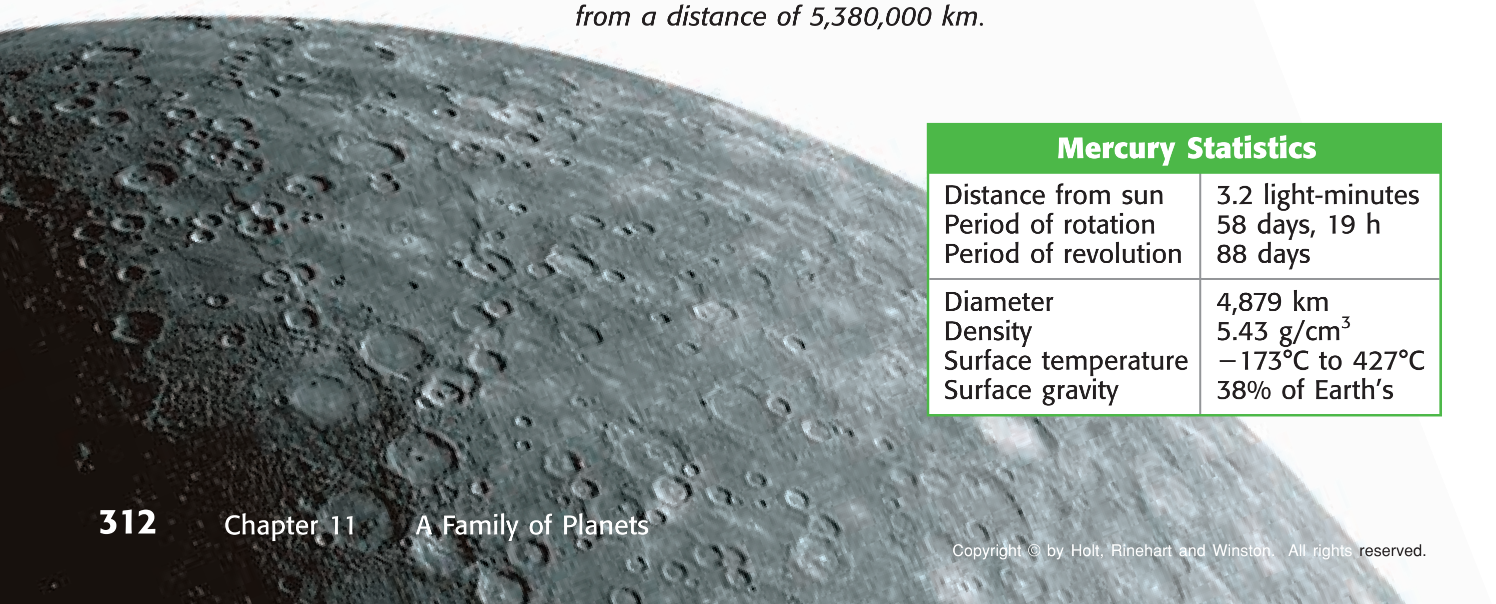
Mercury: Closest to the Sun

If you visited the planet Mercury, shown in **Figure 1,** you would find a very strange world. For one thing, on Mercury you would weigh only 38% of what you weigh on Earth. The weight you have on Earth is due to surface gravity, which is less on less massive planets. Also, because of Mercury's slow rotation, a day on Mercury is almost 59 Earth days long! The amount of time that an object takes to rotate once is called its *period of rotation*. So, Mercury's period of rotation is almost 59 Earth days long.

A Year on Mercury

Another curious thing about Mercury is that its year is only 88 Earth days long. As you know, a *year* is the time that a planet takes to go around the sun once. The motion of a body orbiting another body in space is called *revolution*. The time an object takes to revolve around the sun once is called its *period of revolution*. Every 88 Earth days, or 1.5 Mercurian days, Mercury revolves once around the sun.

Figure 1 *This image of Mercury was taken by the* Mariner 10 *spacecraft on March 24, 1974, from a distance of 5,380,000 km.*



Mercury Statistics	
Distance from sun	3.2 light-minutes
Period of rotation	58 days, 19 h
Period of revolution	88 days
Diameter	4,879 km
Density	5.43 g/cm^3
Surface temperature	−173°C to 427°C
Surface gravity	38% of Earth's

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Venus Statistics	
Distance from sun Period of rotation Period of revolution	6.0 light-minutes 243 days, 16 h (R)* 224 days, 17 h
Diameter Density Surface temperature Surface gravity	12,104 km 5.24 g/cm^3 464°C 91% of Earth's

*R = retrograde rotation

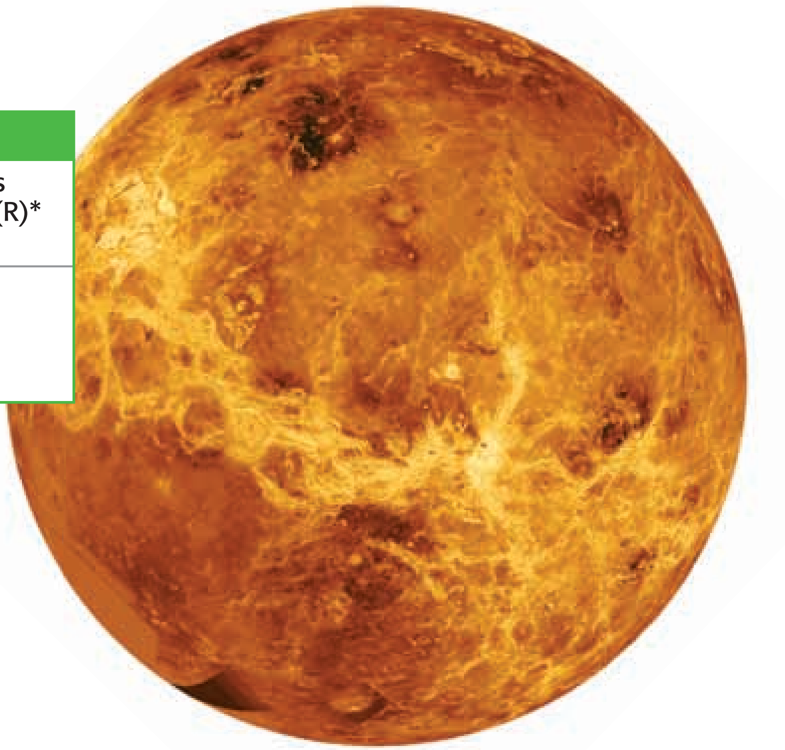


Figure 2 *This image of Venus was taken by* Mariner 10 *on February 5, 1974. The uppermost layer of clouds contains sulfuric acid.*

Venus: Earth's Twin?

Look at **Figure 2.** In many ways, Venus is more like Earth than any other planet. Venus is only slightly smaller, less massive, and less dense than Earth. But in other ways, Venus is very different from Earth. On Venus, the sun rises in the west and sets in the east. The reason is that Venus and Earth rotate in opposite directions. Earth is said to have **prograde rotation** because it appears to spin in a *counterclockwise* direction when it is viewed from above its North Pole. If a planet spins in a *clockwise* direction, the planet is said to have **retrograde rotation.**

prograde rotation the counterclockwise spin of a planet or moon as seen from above the planet's North Pole; rotation in the same direction as the sun's rotation

retrograde rotation the clockwise spin of a planet or moon as seen from above the planet's North Pole

The Atmosphere of Venus

Of the terrestrial planets, Venus has the densest atmosphere. Venus's atmosphere has 90 times the pressure of Earth's atmosphere! The air on Venus is mostly carbon dioxide, but the air is also made of some of the most destructive acids known. The carbon dioxide traps thermal energy from sunlight in a process called the *greenhouse effect*. The greenhouse effect causes Venus's surface temperature to be very high. At 464°C, Venus has the hottest surface of any planet in the solar system.

Mapping Venus's Surface

Between 1990 and 1992, the *Magellan* spacecraft mapped the surface of Venus by using radar waves. The radar waves traveled through the clouds and bounced off the planet's surface. Data gathered from the radar waves showed that Venus, like Earth, has volcanoes.

Reading Check **What technology was used to map the surface of Venus?** (*See the Appendix for answers to Reading Checks.*)

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 3 *Earth is the only planet known to support life.*

Earth: An Oasis in Space

As viewed from space, Earth is like a sparkling blue oasis in a black sea of stars. Constantly changing weather patterns create the swirls of clouds that blanket the blue and brown sphere we call home. Look at **Figure 3.** Why did Earth have such good fortune, while its two nearest neighbors, Venus and Mars, are unsuitable for life as we know it?

Water on Earth

Earth formed at just the right distance from the sun. Earth is warm enough to keep most of its water from freezing. But unlike Venus, Earth is cool enough to keep its water from boiling away. Liquid water is a vital part of the chemical processes that living things depend on for survival.

The Earth from Space

The picture of Earth shown in **Figure 4** was taken from space. You might think that the only goal of space exploration is to make discoveries beyond Earth. But the National Aeronautics and Space Administration (NASA) has a program to study Earth by using satellites in the same way that scientists study other planets. This program is called the Earth Science Enterprise. Its goal is to study the Earth as a global system that is made of smaller systems. These smaller systems include the atmosphere, land, ice, the oceans, and life. The program will also help us understand how humans affect the global environment. By studying Earth from space, scientists hope to understand how different parts of the global system interact.

Reading Check **What is the Earth Science Enterprise?**

Earth Statistics	
Distance from sun	8.3 light-minutes
Period of rotation	23 h, 56 min
Period of revolution	365 days, 6 h
Diameter	12,756 km
Density	5.52 g/cm^3
Surface temperature	−13°C to 37°C
Surface gravity	100% of Earth's

Figure 4 *This image of Earth was taken on December 7, 1972, by the crew of the* Apollo 17 *spacecraft while on their way to the moon.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Mars Statistics	
Distance from sun Period of rotation Period of revolution	12.7 light-minutes 24 h, 40 min 1 year, 322 days
Diameter Density Surface temperature Surface gravity	6,794 km 3.93 g/cm^3 −123°C to 37°C 38% of Earth's

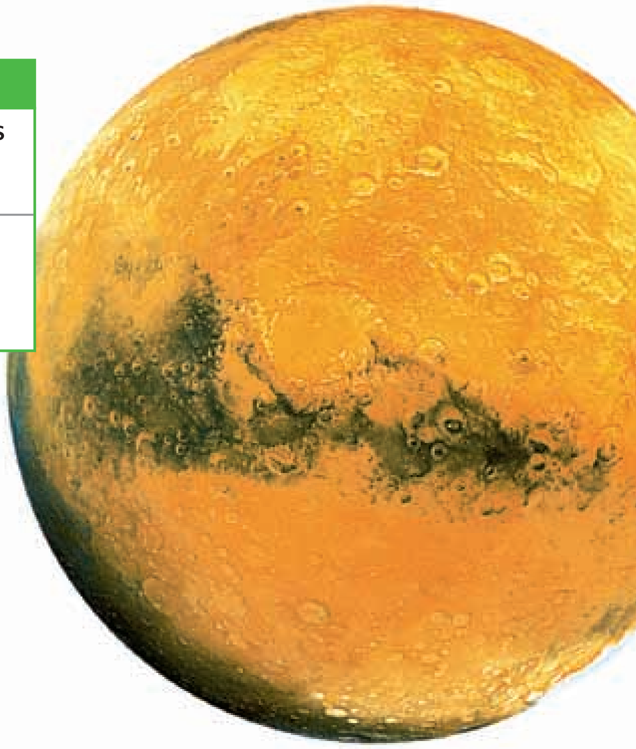


Figure 5 *This Viking orbiter image shows the eastern hemisphere of Mars. The large circular feature in the center is the impact crater Schiaparelli, which has a diameter of 450 km.*

Mars: Our Intriguing Neighbor

Mars, shown in **Figure 5,** is perhaps the most studied planet in the solar system other than Earth. Much of our knowledge of Mars has come from information gathered by spacecraft. *Viking 1* and *Viking 2* landed on Mars in 1976, and *Mars Pathfinder* landed on Mars in 1997.

The Atmosphere of Mars

Because of its thinner atmosphere and greater distance from the sun, Mars is a cold planet. Midsummer temperatures recorded by the *Mars Pathfinder* range from –13°C to –77°C. Martian air is so thin that the air pressure on the surface of Mars is about the same as it is 30 km above Earth's surface. This distance is about 3 times higher than most planes fly! The air pressure is so low that any liquid water would quickly boil away. The only water found on the surface of Mars is in the form of ice.

Water on Mars

Even though liquid water cannot exist on Mars's surface today, there is strong evidence that it existed there in the past. **Figure 6** shows an area on Mars with features that might have resulted from deposition of sediment in a lake. This finding means that in the past Mars might have been a warmer place and had a thicker atmosphere.

Figure 6 *The origin of the features shown in this image is unknown. The features might have resulted from deposition of sediment in a lake.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Where Is the Water Now?

Mars has two polar icecaps made of both frozen water and frozen carbon dioxide. But the polar icecaps do not have enough water to create a thick atmosphere or rivers. Looking closely at the walls of some Martian craters, scientists have found that the debris around the craters looks as if it were made by the flow of mud rather than by dry soil. In this case, where might some of the "lost" Martian water have gone? Many scientists think that it is frozen beneath the Martian soil.

CONNECTION TO Physics

WRITING SKILL **Boiling Point on Mars** At sea level on Earth's surface, water boils at 100°C. But if you try to boil water on top of a high mountain, you will find that the boiling point is lower than 100°C. Do some research to find out why. Then, in your own words, explain why liquid water cannot exist on Mars, based on what you learned.

Martian Volcanoes

Mars has a rich volcanic history. Unlike Earth, where volcanoes exist in many places, Mars has only two large volcanic systems. The largest, the Tharsis region, stretches 8,000 km across the planet. The largest mountain in the solar system, Olympus Mons, is an extinct shield volcano similar to Mauna Kea on the island of Hawaii. Mars not only is smaller and cooler than Earth but also has a slightly different chemical makeup. This makeup may have kept the Martian crust from moving around as Earth's crust does. As a result, the volcanoes kept building up in the same spots on Mars. Images and data sent back by probes such as the *Sojourner* rover, shown in **Figure 7,** are helping to explain Mars's mysterious past.

Reading Check **What characteristics of Mars may explain why Mars has only two large volcanic systems?**

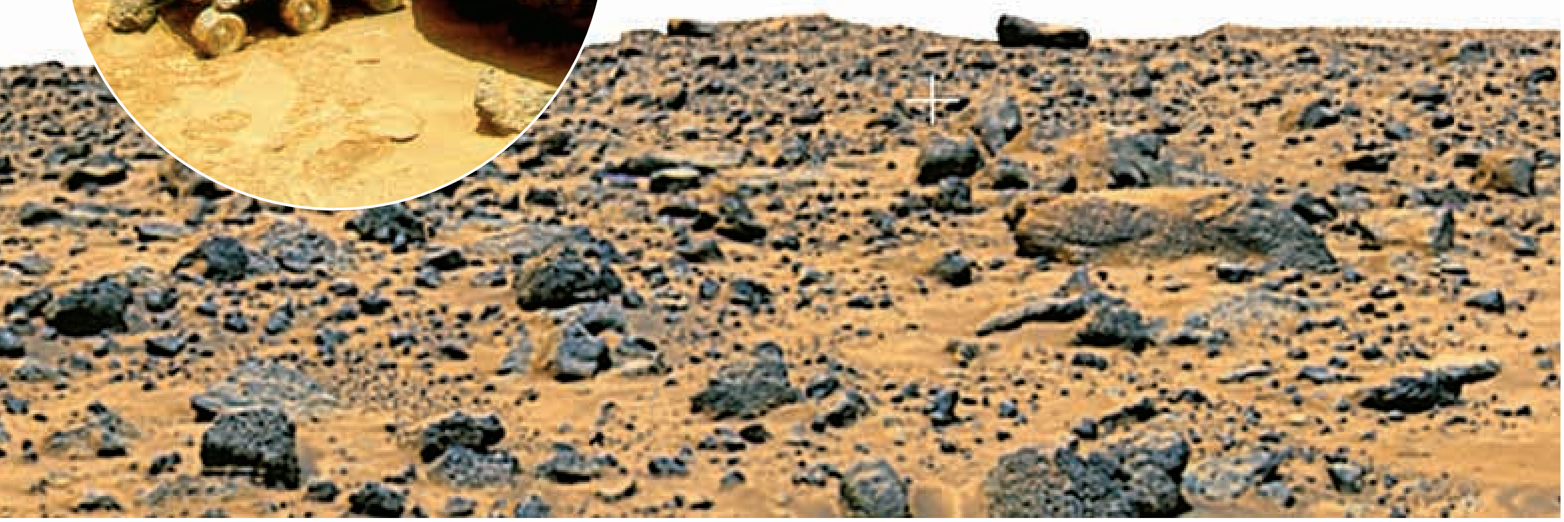


Figure 7 *The* Sojourner *rover, part of the Mars Pathfinder mission, is shown here creeping up to a rock named Yogi to measure its composition. The solar panel on the rover's back collected the solar energy used to power the rover's motor.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Missions to Mars

Scientists are still intrigued by the mysteries of Mars. Several recent missions to Mars were launched to gain a better understanding of the Martian world. **Figure 8** shows the *Mars Express Orbiter,* which was launched by the European Space Agency (ESA) in 2003, and was designed to help scientists determine the composition of the Martian atmosphere and Martian climate. Also, in 2003, NASA launched the Twin Rover mission to Mars. These exploration rovers are designed to gather information that may help scientists determine if life ever existed on Mars. In addition, information collected by these rovers may help scientists prepare for human exploration on Mars.

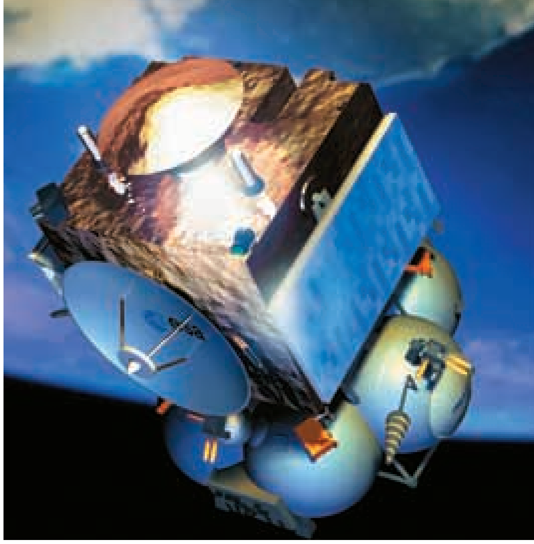


Figure 8 *The* Mars Express Orbiter *will help scientists study Mars's atmosphere.*

SECTION Review

Summary

- A period of rotation is the length of time that an object takes to rotate once on its axis.
- A period of revolution is the length of time that an object takes to revolve around the sun.
- Mercury is the planet closest to the sun. Of all the terrestrial planets, Venus has the densest atmosphere. Earth is the only planet known to support life. Mars has a rich volcanic history and shows evidence of once having had water.

Using Key Terms

1. In your own words, write a definition for the term *terrestrial planet.*

For the pair of terms below, explain how the meanings of the terms differ.

2. *prograde rotation* and *retrograde rotation*

Understanding Key Ideas

3. Scientists believe that the water on Mars now exists as
   a. polar icecaps.
   b. dry riverbeds.
   c. ice beneath the Martian soil.
   d. Both (a) and (c)
4. List three differences between and three similarities of Venus and Earth.
5. What is the difference between a planet's period of rotation and its period of revolution?
6. What are some of the characteristics of Earth that make it suitable for life?
7. Explain why the surface temperature of Venus is higher than the surface temperatures of the other planets in our solar system.

Math Skills

8. Mercury has a period of rotation equal to 58.67 Earth days. Mercury's period of revolution is equal to 88 Earth days. How many times does Mercury rotate during one revolution around the sun?

Critical Thinking

9. **Making Inferences** What type of information can we get by studying Earth from space?
10. **Analyzing Ideas** What type of evidence found on Mars suggests that Mars may have been a warmer place and had a thicker atmosphere?

SCILINKS® NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: The Inner Planets
SciLinks code: HSM0798

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 3

The Outer Planets

What do all the outer planets except for Pluto have in common?

Except for Pluto, the outer planets are very large planets that are made mostly of gases. These planets are called gas giants. **Gas giants** are planets that have deep, massive atmospheres rather than hard and rocky surfaces like those of the inner planets.

READING WARM-UP

Objectives

- Explain how gas giants are different from terrestrial planets.
- Describe the individual characteristics of Jupiter, Saturn, Uranus, Neptune, and Pluto.

Terms to Learn

gas giant

READING STRATEGY

Prediction Guide Before reading this section, write the title of each heading in this section. Next, under each heading write what you think you will learn.

gas giant a planet that has a deep, massive atmosphere, such as Jupiter, Saturn, Uranus, or Neptune

Jupiter: A Giant Among Giants

Jupiter is the largest planet in our solar system. Like the sun, Jupiter is made mostly of hydrogen and helium. The outer part of Jupiter's atmosphere is made of layered clouds of water, methane, and ammonia. The beautiful colors you see in **Figure 1** are probably due to small amounts of organic compounds. At a depth of about 10,000 km into Jupiter's atmosphere, the pressure is high enough to change hydrogen gas into a liquid. Deeper still, the pressure changes the liquid hydrogen into a liquid, metallic state. Unlike most planets, Jupiter radiates much more energy into space than it receives from the sun. The reason is that Jupiter's interior is very hot. Another striking feature of Jupiter is the Great Red Spot, a storm system that is more than 400 years old and is about 3 times the diameter of Earth!

NASA Missions to Jupiter

NASA has sent five missions to Jupiter. These include two Pioneer missions, two Voyager missions, and the recent Galileo mission. The *Voyager 1* and *Voyager 2* spacecraft sent back images that revealed a thin, faint ring around Jupiter. The Voyager missions also gave us the first detailed images of Jupiter's moons. The *Galileo* spacecraft reached Jupiter in 1995 and sent a probe into Jupiter's atmosphere. The probe sent back data on Jupiter's composition, temperature, and pressure.

Figure 1 *This* Voyager 2 *image of Jupiter was taken at a distance of 28.4 million kilometers. Io, one of Jupiter's largest moons, can also be seen in this image.*

Jupiter Statistics	
Distance from sun	43.3 light-minutes
Period of rotation	9 h, 54 min
Period of revolution	11 years, 313 days
Diameter	142,984 km
Density	1.33 g/cm^3
Temperature	−110°C
Gravity	236% of Earth's

Copyright © by Holt, Rinehart and Winston. All rights reserved.

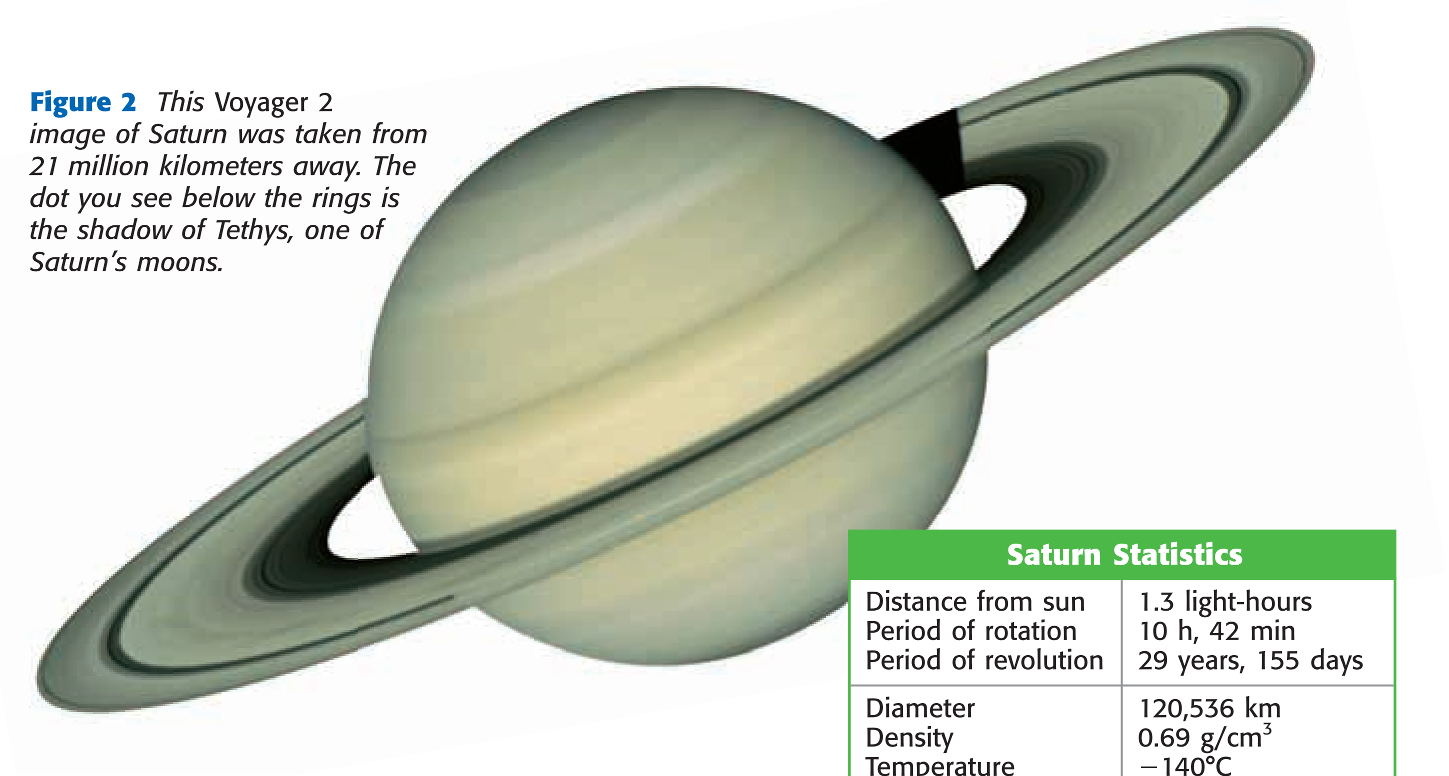


Figure 2 *This* Voyager 2 *image of Saturn was taken from 21 million kilometers away. The dot you see below the rings is the shadow of Tethys, one of Saturn's moons.*

Saturn Statistics	
Distance from sun Period of rotation Period of revolution	1.3 light-hours 10 h, 42 min 29 years, 155 days
Diameter Density Temperature Gravity	120,536 km 0.69 g/cm^3 −140°C 92% of Earth's

Saturn: Still Forming

Saturn, shown in **Figure 2,** is the second-largest planet in the solar system. Saturn has roughly 764 times the volume of Earth and is 95 times more massive than Earth. Its overall composition, like Jupiter's, is mostly hydrogen and helium. But methane, ammonia, and ethane are found in the upper atmosphere. Saturn's interior is probably much like Jupiter's. Also, like Jupiter, Saturn gives off much more energy than it receives from the sun. Scientists think that Saturn's extra energy comes from helium falling out of the atmosphere and sinking to the core. In other words, Saturn is still forming!

The Rings of Saturn

Although all of the gas giants have rings, Saturn's rings are the largest. Saturn's rings have a total diameter of 272,000 km. Yet, Saturn's rings are only a few hundred meters thick. The rings are made of icy particles that range in size from a few centimeters to several meters wide. **Figure 3** shows a close-up view of Saturn's rings.

Reading Check **What are Saturn's rings made of?** (*See the Appendix for answers to Reading Checks.*)

NASA's Exploration of Saturn

Launched in 1997, the *Cassini* spacecraft is designed to study Saturn's rings, moons, and atmosphere. The spacecraft is also designed to return more than 300,000 color images of Saturn.

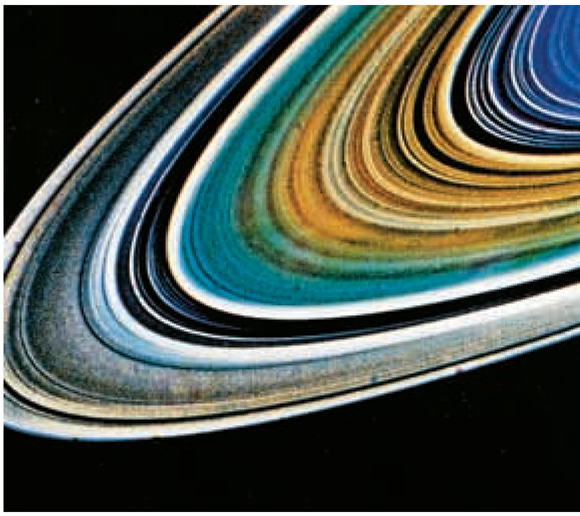


Figure 3 *The different colors in this* Voyager 2 *image of Saturn's rings show differences in the rings' chemical composition.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 4 *This image of Uranus was taken by* Voyager 2 *at a distance of 9.1 million kilometers.*

Uranus Statistics	
Distance from sun Period of rotation Period of revolution	2.7 light-hours 17 h, 12 min (R)* 83 years, 273 days
Diameter Density Temperature Gravity	51,118 km 1.27 g/cm^3 −195°C 89% of Earth's

*R = retrograde rotation

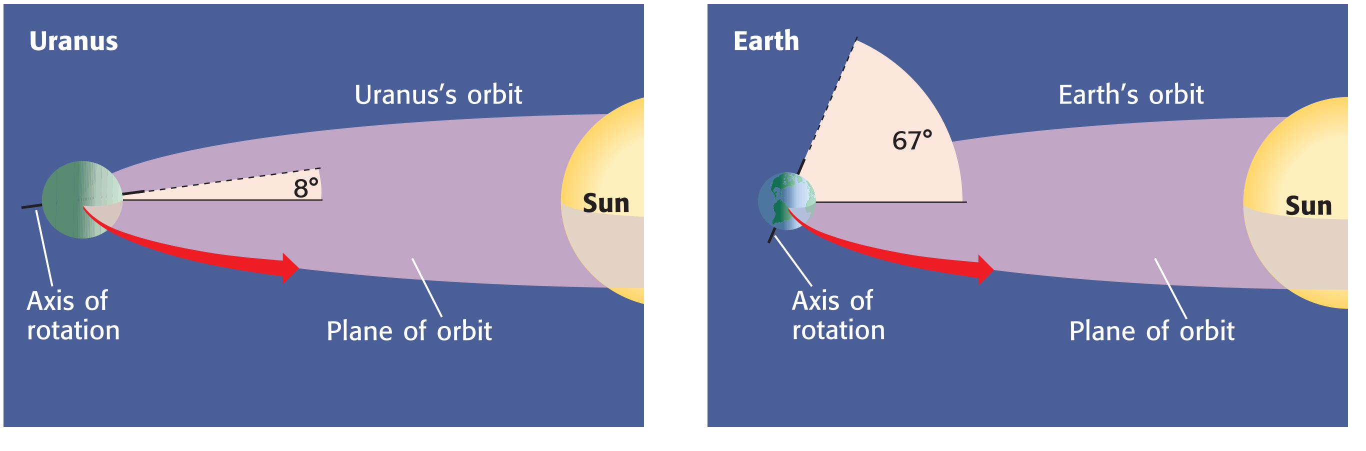
Uranus: A Small Giant

Uranus (YOOR uh nuhs) was discovered by the English amateur astronomer William Herschel in 1781. The atmosphere of Uranus is mainly hydrogen and methane. Because these gases absorb the red part of sunlight very strongly, Uranus appears blue-green in color, as shown in **Figure 4.** Uranus and Neptune have much less mass than Jupiter, but their densities are similar. This suggests that their compositions are different from Jupiter's. They may have lower percentages of light elements and a greater percentage of water.

A Tilted Planet

Unlike most other planets, Uranus is tipped over on its side. So, its axis of rotation is tilted by almost 90° and lies almost in the plane of its orbit, as shown in **Figure 5.** For part of a Uranus year, one pole points toward the sun while the other pole is in darkness. At the other end of Uranus's orbit, the poles are reversed. Some scientists think that early in its history, Uranus may have been hit by a massive object that tipped the planet over.

Figure 5 *Uranus's axis of rotation is tilted so that the axis is nearly parallel to the plane of Uranus's orbit. In contrast, the axes of most other planets are closer to being perpendicular to the plane of the planets' orbits.*



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Neptune: The Blue World

Irregularities in the orbit of Uranus suggested to early astronomers that there must be another planet beyond it. They thought that the gravity of this new planet pulled Uranus off its predicted path. By using the predictions of the new planet's orbit, astronomers discovered the planet Neptune in 1846. Neptune is shown in **Figure 6.**

The Atmosphere of Neptune

The *Voyager 2* spacecraft sent back images that provided much new information about Neptune's atmosphere. Although the composition of Neptune's atmosphere is similar to that of Uranus's atmosphere, Neptune's atmosphere has belts of clouds that are much more visible. At the time of *Voyager 2*'s visit, Neptune had a Great Dark Spot like the Great Red Spot on Jupiter. And like the interiors of Jupiter and Saturn, Neptune's interior releases thermal energy to its outer layers. This release of energy helps the warm gases rise and the cool gases sink, which sets up the wind patterns in the atmosphere that create the belts of clouds. *Voyager 2* images also revealed that Neptune has a set of very narrow rings.

Reading Check **What characteristic of Neptune's interior accounts for the belts of clouds in Neptune's atmosphere?**

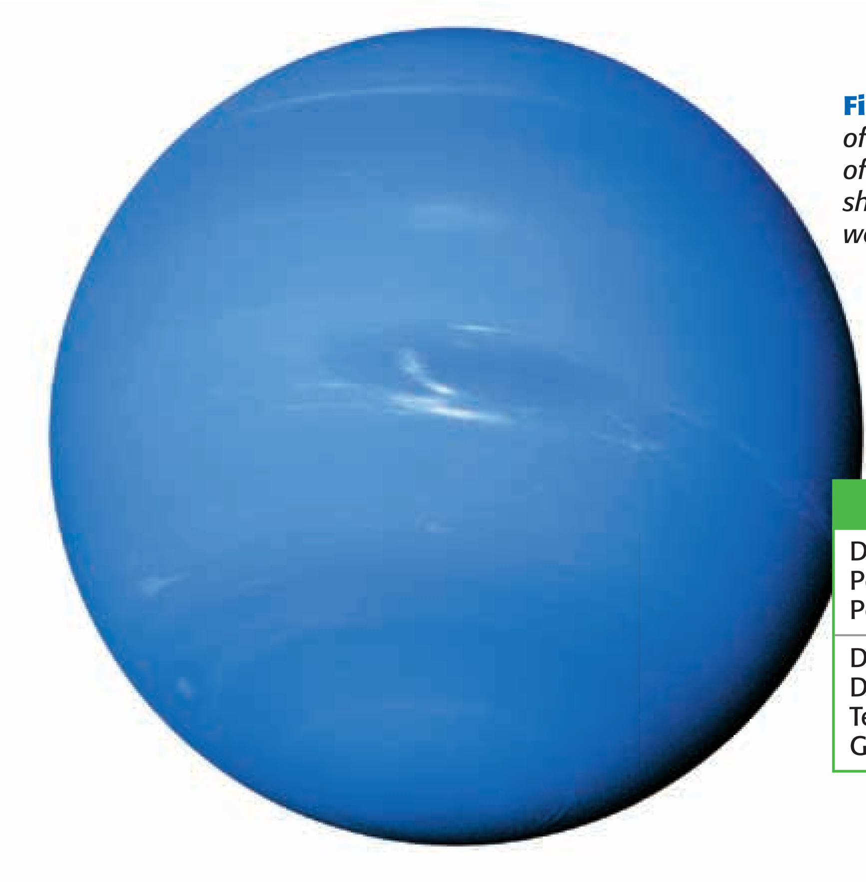


Figure 6 *This* Voyager 2 *image of Neptune, taken at a distance of more than 7 million kilometers, shows the Great Dark Spot as well as some bright cloud bands.*

Neptune Statistics	
Distance from sun	4.2 light-hours
Period of rotation	16 h, 6 min
Period of revolution	163 years, 263 days
Diameter	49,528 km
Density	1.64 g/cm^3
Temperature	−200°C
Gravity	112% of Earth's

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 7 *This* Hubble Space Telescope *image is one of the clearest ever taken of Pluto* (left) *and its moon, Charon* (right).

Pluto Statistics	
Distance from sun Period of rotation Period of revolution	5.4 light-hours 6 days, 10 h (R)* 248 years, 4 days
Diameter Density Surface temperature Surface gravity	2,390 km 1.75 g/cm^3 −225°C 6% of Earth's

*R = retrograde rotation

Pluto: The Mystery Planet

Further study of Neptune showed some irregularities in Neptune's orbit. This finding led many scientists to believe there was yet another planet beyond Neptune. The mystery planet was finally discovered in 1930.

A Small World

The mystery planet, now called Pluto, is the farthest planet from the sun. Less than half the size of Mercury, Pluto is also the smallest planet. Pluto's moon, Charon (KER uhn), is more than half its size! In fact, Charon is the largest satellite relative to its planet in the solar system. **Figure 7** shows Pluto and Charon together. From Earth, it is hard to separate the images of Pluto and Charon because the bodies are so far away. **Figure 8** shows how far from the sun Pluto and Charon really are. From Pluto, the sun looks like a very distant bright star.

From calculations of Pluto's density, scientists know that Pluto must be made of rock and ice. Pluto is covered by frozen nitrogen, but Charon is covered by frozen water. Scientists believe Pluto has a thin atmosphere of methane.

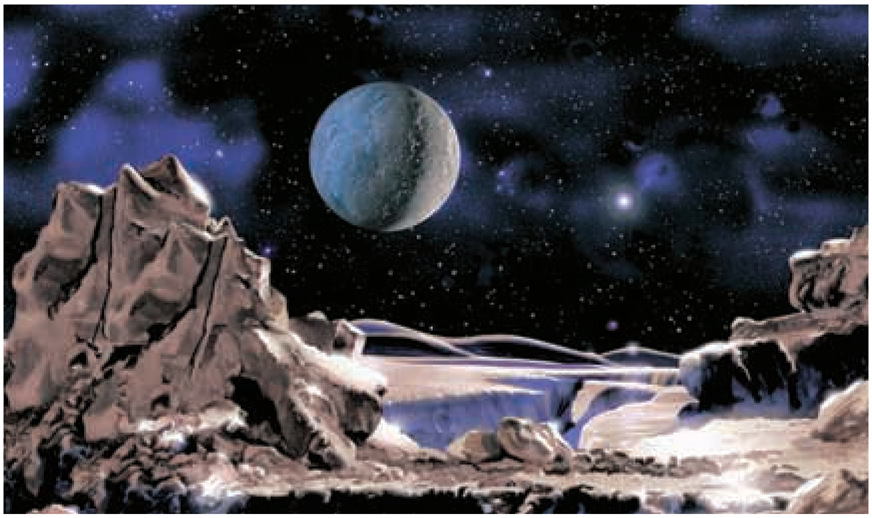


Figure 8 *An artist's view of the sun and Charon from Pluto shows just how little light and heat Pluto receives from the sun.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

A True Planet?

Because Pluto is so small and is so unusual, some scientists think that it should not be classified as a planet. In fact, some scientists agree that Pluto could be considered a large asteroid or comet—large enough to have its own satellite. However, because Pluto was historically classified as a planet, it most likely will remain so.

Pluto is the only planet that has not been visited by a NASA mission. However, plans are underway to visit Pluto and Charon in 2006. During this mission, scientists hope to learn more about this unusual planet and map the surface of both Pluto and Charon.

SCHOOL to HOME

Surviving Space

WRITING SKILL Imagine it is the year 2150 and you are flying a spacecraft to Pluto. Suddenly, your systems fail, giving you only one chance to land safely. You can't head back to Earth. With a parent, write a paragraph explaining which planet you would choose to land on.

ACTIVITY

SECTION Review

Summary

- Jupiter is the largest planet in our solar system. Energy from the interior of Jupiter is transferred to its exterior.
- Saturn is the second-largest planet and, in some ways, is still forming as a planet.
- Uranus's axis of rotation is tilted by almost 90°.
- Neptune has a faint ring, and its atmosphere contains belts of clouds.
- Pluto is the smallest planet, and its moon, Charon, is more than half its size.

Using Key Terms

1. In your own words, write a definition for the term *gas giant*.

Understanding Key Ideas

2. The many colors of Jupiter's atmosphere are probably caused by _____ in the atmosphere.
   a. clouds of water
   b. methane
   c. ammonia
   d. organic compounds
3. Why do scientists claim that Saturn, in a way, is still forming?
4. Why does Uranus have a blue green color?
5. What is unusual about Pluto's moon, Charon?
6. What is the Great Red Spot?
7. Explain why Jupiter radiates more energy into space than it receives from the sun.
8. How do the gas giants differ from the terrestrial planets?
9. What is so unusual about Uranus's axis of rotation?

Math Skills

10. Pluto is 5.5 light-hours from the sun. How far is Pluto from the sun in astronomical units? (Hint: 1 AU = 8.3 light-minutes)
11. If Jupiter is 43.3 light-minutes from the sun and Neptune is 4.2 light-hours from the sun, how far from Jupiter is Neptune?

Critical Thinking

12. **Evaluating Data** What conclusions can your draw about the properties of a planet just by knowing how far it is from the sun?
13. **Applying Concepts** Why isn't the word *surface* included in the statistics for the gas giants?

SCILINKS® NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: The Outer Planets
SciLinks code: HSM1091

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 4

Moons

If you could, which moon would you visit? With volcanoes, craters, and possible underground oceans, the moons in our solar system would be interesting places to visit.

READING WARM-UP

Objectives

- Describe the individual characteristics of the moons of other planets.

Terms to Learn

satellite

READING STRATEGY

Reading Organizer As you read this section, make a table comparing Earth's moon with the moons of other planets.

satellite a natural or artificial body that revolves around a planet

Natural or artificial bodies that revolve around larger bodies such as planets are called **satellites.** Except for Mercury and Venus, all of the planets have natural satellites called *moons*.

Luna: The Moon of Earth

Scientists have learned a lot from studying Earth's moon, which is also called *Luna*. The lunar rocks brought back during the Apollo missions were found to be about 4.6 billion years old. Because these rocks have hardly changed since they formed, scientists know the solar system itself is about 4.6 billion years old.

The Surface of the Moon

As you can see in **Figure 1,** the moon's history is written on its face. The surfaces of bodies that have no atmospheres preserve a record of almost all of the impacts that the bodies have had. Because scientists now know the age of the moon, they can count the number of impact craters to find the rate of cratering since the birth of our solar system. By knowing the rate of cratering, scientists are able to use the number of craters on any body to estimate how old the body's surface is.

Reading Check **What can the rate of cratering tell scientists?** *(See the Appendix for answers to Reading Checks.)*

Figure 1 *This image of the moon was taken by the* Galileo *spacecraft while on its way to Jupiter. The large, dark areas are lava plains called* maria.

Moon Statistics	
Period of rotation	27 days, 9 hours
Period of revolution	27 days, 7 hours
Diameter	3,475 km
Density	3.34 g/cm^3
Surface temperature	−170 to 134°C
Surface gravity	16% of Earth's

Copyright © by Holt, Rinehart and Winston. All rights reserved.

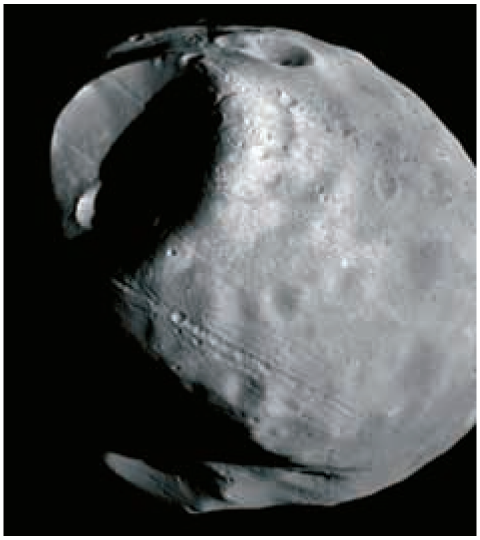


Figure 2 *Mars has two moons. Phobos, on the left, is Mars' largest moon. At right is the smaller moon, Deimos.*

The Moons of Other Planets

The moons of the other planets range in size from very small to as large as terrestrial planets. All of the gas giants have multiple moons, and scientists are still discovering new moons. Some moons have very elongated, or elliptical, orbits, and some moons even orbit their planet backward! Many of the very small moons may be captured asteroids. As scientists are learning from recent space missions, moons may be some of the most bizarre and interesting places in the solar system!

The Moons of Mars

Mars's two moons, Phobos and Deimos, are small, oddly shaped satellites. Both moons are very dark, as you can see in **Figure 2**. Their surface materials are much like those of some asteroids—large, rocky bodies in space. Scientists think that these two moons are asteroids caught by Mars's gravity.

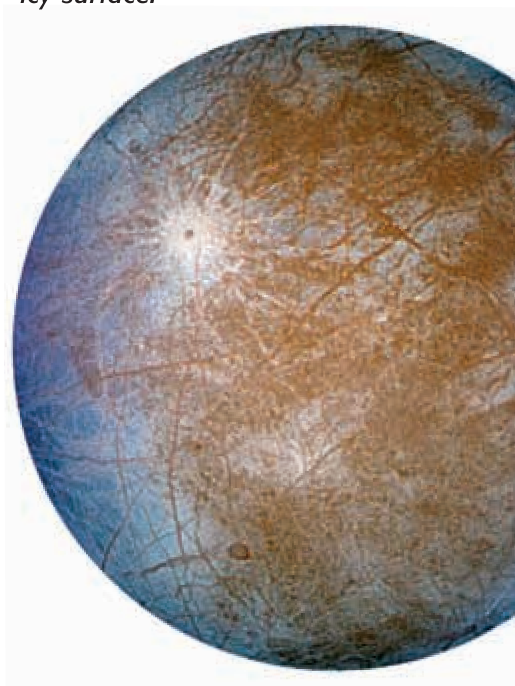
The Moons of Jupiter

Jupiter has dozens of moons. The four largest moons—Ganymede, Callisto, Io, and Europa—were discovered in 1610 by Galileo. They are known as the *Galilean satellites*. The largest moon, Ganymede, is even larger than the planet Mercury! Many of the smaller moons probably are captured asteroids.

The Galilean satellite closest to Jupiter is Io, a truly bizarre world. Io is caught in a gravitational tug of war between Jupiter and Io's nearest neighbor, the moon Europa. This constant tugging stretches Io a little and causes it to heat up. As a result, Io is the most volcanically active body in the solar system!

Recent pictures of the moon Europa, shown in **Figure 3,** support the idea that liquid water may lie beneath the moon's icy surface. This idea makes many scientists wonder if life could have evolved in the underground oceans of Europa.

Figure 3 *Europa, Jupiter's fourth largest moon, might have liquid water beneath its icy surface.*



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 4 *Titan is Saturn's largest moon.*

The Moons of Saturn

Like Jupiter, Saturn has dozens of moons. Most of these moons are small bodies that are made mostly of frozen water but contain some rocky material. The largest satellite, Titan, was discovered in 1655 by Christiaan Huygens. In 1980, the *Voyager 1* spacecraft flew past Titan and discovered a hazy orange atmosphere, as shown in **Figure 4.** Earth's early atmosphere may have been much like Titan's is now. In 1997, NASA launched the *Cassini* spacecraft to study Saturn and its moons, including Titan. By studying Titan, scientists hope to learn more about how life began on Earth.

Reading Check **How can scientists learn more about how life began on Earth by studying Titan?**

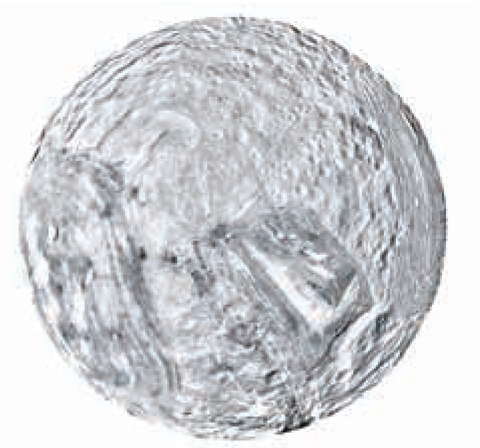


Figure 5 *This* Voyager 2 *image shows Miranda, the most unusual moon of Uranus. Its patchwork terrain indicates that it has had a violent history.*

The Moons of Uranus

Uranus has several moons. Like the moons of Saturn, Uranus's largest moons are made of ice and rock and are heavily cratered. The small moon Miranda, shown in **Figure 5,** has some of the strangest features in the solar system. Miranda's surface has smooth, cratered plains as well as regions that have grooves and cliffs. Scientists think that Miranda may have been hit and broken apart in the past. Gravity pulled the pieces together again, leaving a patchwork surface.

The Moons of Neptune

Neptune has several known moons, only one of which is large. This large moon, Triton, is shown in **Figure 6.** It revolves around the planet in a *retrograde,* or "backward," orbit. This orbit suggests that Triton may have been captured by Neptune's gravity. Triton has a very thin atmosphere made mostly of nitrogen gas. Triton's surface is mostly frozen nitrogen and methane. *Voyager 2* images reveal that Triton is geologically active. "Ice volcanoes," or geysers, eject nitrogen gas high into the atmosphere. The other moons of Neptune are small, rocky worlds much like the smaller moons of Saturn and Jupiter.

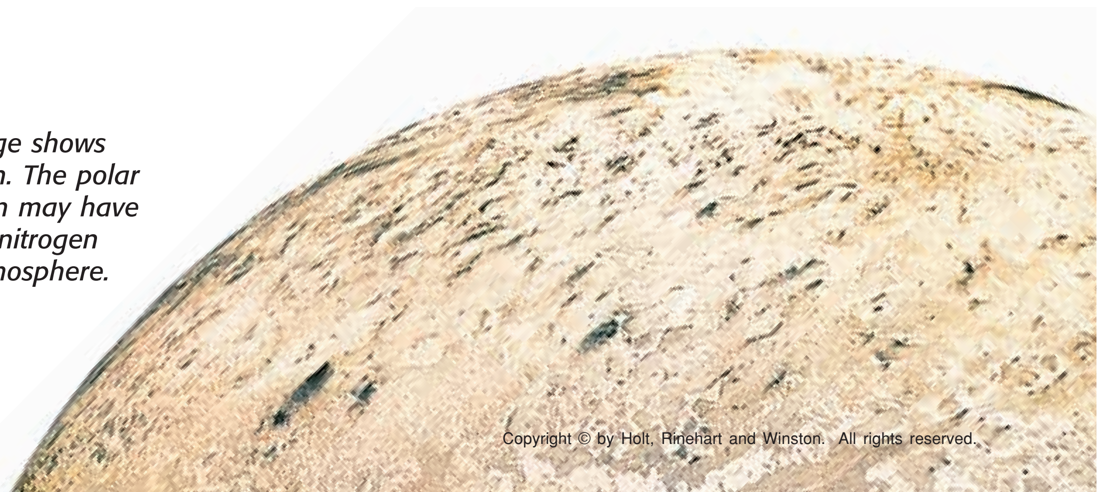


Figure 6 *This* Voyager 2 *image shows Neptune's largest moon, Triton. The polar icecap currently facing the sun may have a slowly evaporating layer of nitrogen ice, adding to Triton's thin atmosphere.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

The Moon of Pluto

Pluto's only known moon, Charon, was discovered in 1978. **Figure 7** shows what scientists think Charon might look like. Charon's period of revolution is the same as Pluto's period of rotation—about 6.4 days. So, one side of Pluto always faces Charon. In other words, if you stood on the surface of Pluto, Charon would always occupy the same place in the sky. Imagine Earth's moon staying in the same place every night! Charon's orbit around Pluto is tilted relative to Pluto's orbit around the sun. As a result, Pluto, as seen from Earth, is sometimes eclipsed by Charon. But don't hold your breath; this eclipse happens only once every 120 years!

Reading Check **How often is Pluto eclipsed by Charon?**

Figure 7 *Charon, Pluto's only known moon, is almost as big as Pluto itself!*

SECTION Review

Summary

- Earth has one moon which is named Luna.
- Mars has 2 moons, Phobos and Deimos.
- Jupiter has dozens of moons. Ganymede, Io, Callisto, and Europa are the largest.
- Saturn has dozens of moons. Titan is the largest.
- Uranus has several moons; Miranda is the most unusual.
- Neptune has several moons. Triton is the largest.
- Pluto has one known moon, Charon.

Using Key Terms

1. In your own words, write a definition for the term *satellite*.

Understanding Key Ideas

2. Which of the following is a moon of Neptune?
   a. Charon
   b. Triton
   c. Miranda
   d. Titan
3. Which of the following is a Galilean satellite?
   a. Phobos
   b. Deimos
   c. Ganymede
   d. Charon
4. What characteristic of Neptune's moon Triton leads scientists to think that it may have been captured by Neptune's gravity?

Critical Thinking

5. **Analyzing Methods** How can astronomers use the age of a lunar rock to estimate the age of the surface of a planet such as Mercury?
6. **Identifying Relationships** Charon stays in the same place in Pluto's sky. Why does this occur? How does the movement of Charon compare with the movement of the Earth's moon?

SCILINKS® NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Moons of Other Planets
SciLinks code: HSM0993

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 5

Small Bodies in the Solar System

Imagine you are traveling in a spacecraft to explore the edge of our solar system. You see several small bodies, as well as the planets and their satellites, moving through space.

The solar system contains not only planets and moons but other small bodies, including comets, asteroids, and meteoroids. Scientists study these objects to learn about the composition of the solar system.

READING WARM-UP

Objectives

- Explain why comets, asteroids, and meteoroids are important to the study of the formation of the solar system.
- Describe the similarities of and differences between asteroids and meteoroids.
- Explain how cosmic impacts may affect life on Earth.

Terms to Learn

comet	meteoroid
asteroid	meteorite
asteroid belt	meteor

READING STRATEGY

Discussion Read this section silently. Write down questions that you have about this section. Discuss your questions in a small group.

Comets

A small body of ice, rock, and cosmic dust loosely packed together is called a **comet**. Some scientists refer to comets as "dirty snowballs" because of their composition. Comets formed in the cold, outer solar system. Nothing much has happened to comets since the birth of the solar system 4.6 billion years ago. Comets are probably left over from the time when the planets formed. As a result, each comet is a sample of the early solar system. Scientists want to learn more about comets to piece together the history of our solar system.

Comet Tails

When a comet passes close enough to the sun, solar radiation heats the ice so that the comet gives off gas and dust in the form of a long tail, as shown in **Figure 1.** Sometimes, a comet has two tails—an *ion tail* and a *dust tail.* The ion tail is made of electrically charged particles called *ions*. The solid center of a comet is called its *nucleus*. Comet nuclei can range in size from less than half a kilometer to more than 100 km in diameter.

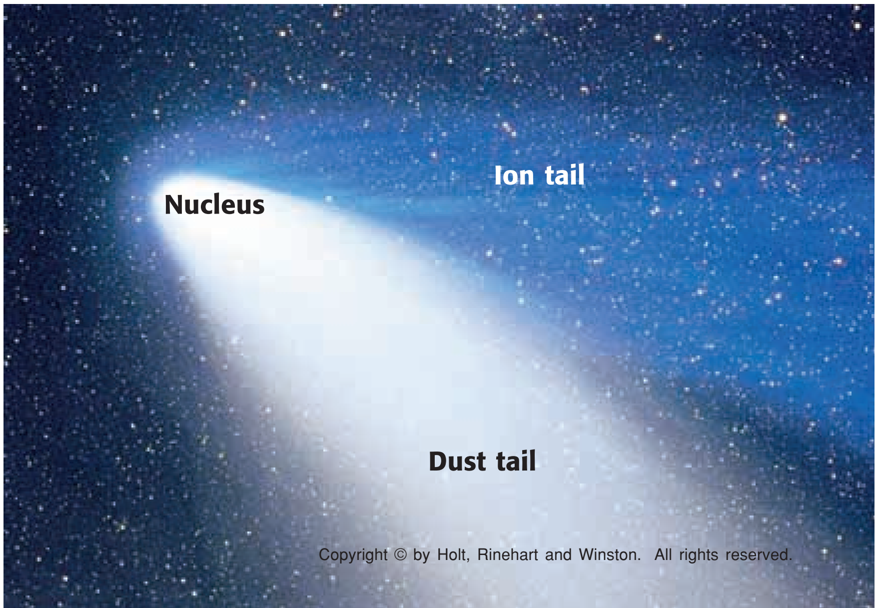


Figure 1 *This image shows the physical features of a comet when it is close to the sun. The nucleus of a comet is hidden by brightly lit gases and dust.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

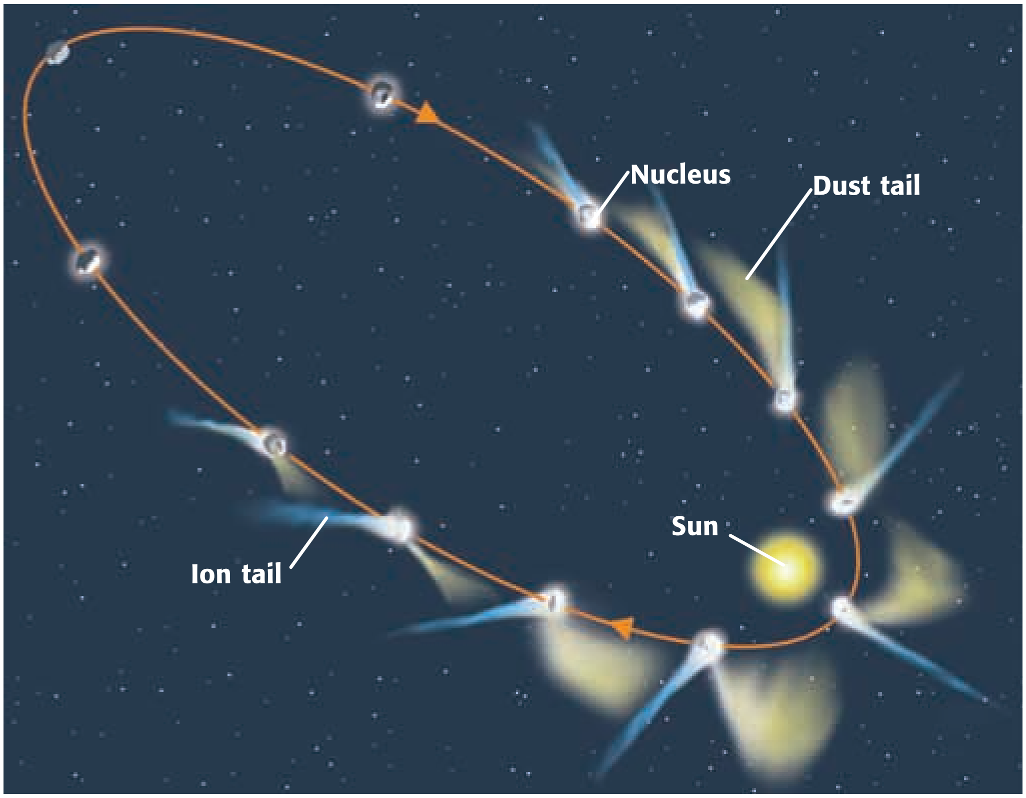


Figure 2 *Comets have very elongated orbits. When a comet gets close to the sun, the comet can develop one or two tails.*

Comet Orbits

The orbits of all bodies that move around the sun are ellipses. *Ellipses* are circles that are somewhat stretched out of shape. The orbits of most planets are close to perfect circles, but the orbits of comets are very elongated.

Notice in **Figure 2** that a comet's ion tail always points away from the sun. The reason is that the ion tail is blown away from the sun by *solar wind*, which is also made of ions. The dust tail tends to follow the comet's orbit around the sun. Dust tails do not always point away from the sun. When a comet is close to the sun, its tail can extend millions of kilometers through space!

Comet Origins

Where do comets come from? Many scientists think that comets come from the Oort (AWRT) cloud, a spherical region that surrounds the solar system. When the gravity of a passing planet or star disturbs part of this cloud, comets can be pulled toward the sun. Another recently discovered region where comets exist is the Kuiper (KIE puhr) belt, which is the region outside the orbit of Neptune.

Reading Check **From which two regions do comets come?** (*See the Appendix for answers to Reading Checks.*)

comet a small body of ice, rock, and cosmic dust that follows an elliptical orbit around the sun and that gives off gas and dust in the form of a tail as it passes close to the sun

CONNECTION TO Language Arts

WRITING SKILL **Interplanetary Journalist** In 1994, the world watched in awe as parts of the comet Shoemaker-Levy 9 collided with Jupiter, which caused enormous explosions. Imagine you were an interplanetary journalist who traveled through space to observe the comet during this time. Write an article describing your adventure.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

asteroid a small, rocky object that orbits the sun, usually in a band between the orbits of Mars and Jupiter

asteroid belt the region of the solar system that is between the orbits of Mars and Jupiter and in which most asteroids orbit

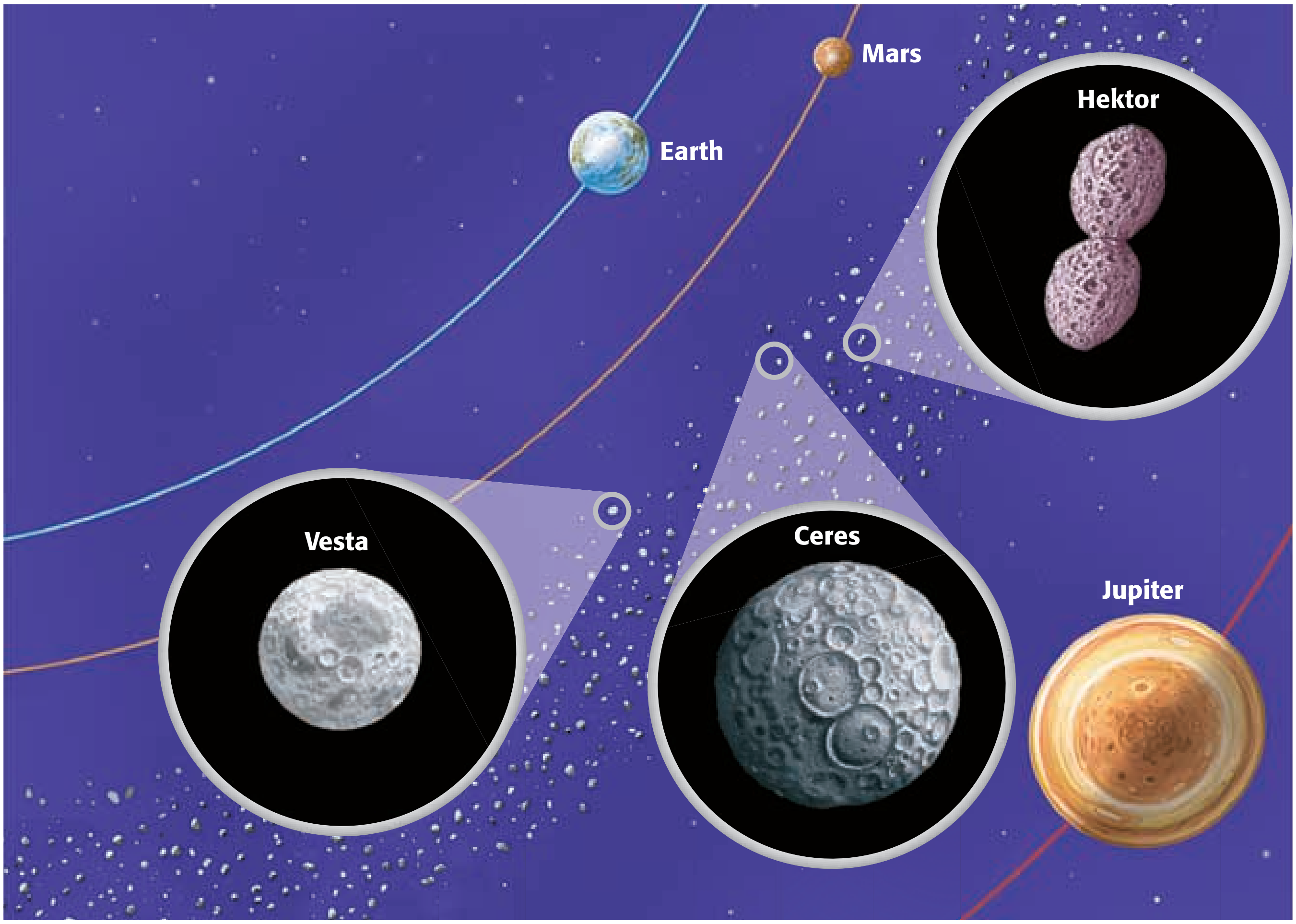
Asteroids

Small, rocky bodies that revolve around the sun are called **asteroids.** They range in size from a few meters to more than 900 km in diameter. Asteroids have irregular shapes, although some of the larger ones are spherical. Most asteroids orbit the sun in the asteroid belt. The **asteroid belt** is a wide region between the orbits of Mars and Jupiter. Like comets, asteroids are thought to be material left over from the formation of the solar system.

Types of Asteroids

The composition of asteroids varies depending on where they are located within the asteroid belt. In the outermost region of the asteroid belt, asteroids have dark reddish brown to black surfaces. This coloring may indicate that the asteroids are rich in organic material. Asteroids that have dark gray surfaces are rich in carbon. In the innermost part of the asteroid belt are light gray asteroids that have either a stony or metallic composition. **Figure 3** shows three asteroids: Hektor, Ceres, and Vesta.

Figure 3 **The Asteroid Belt**



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Meteoroids

Meteoroids are similar to but much smaller than asteroids. A **meteoroid** is a small, rocky body that revolves around the sun. Most meteoroids are probably pieces of asteroids. A meteoroid that enters Earth's atmosphere and strikes the ground is called a **meteorite.** As a meteoroid falls into Earth's atmosphere, the meteoroid moves so fast that its surface melts. As the meteoroid burns up, it gives off an enormous amount of light and thermal energy. From the ground, you see a spectacular streak of light, or a shooting star. A **meteor** is the bright streak of light caused by a meteoroid or comet dust burning up in the atmosphere.

meteoroid a relatively small, rocky body that travels through space

meteorite a meteoroid that reaches the Earth's surface without burning up completely

meteor a bright streak of light that results when a meteoroid burns up in the Earth's atmosphere

Meteor Showers

Many of the meteors that we see come from very small (dust-sized to pebble-sized) rocks. Even so, meteors can be seen on almost any night if you are far enough away from a city to avoid the glare of its lights. At certain times of the year, you can see large numbers of meteors, as shown in **Figure 4.** These events are called *meteor showers*. Meteor showers happen when Earth passes through the dusty debris that comets leave behind.

Figure 4 *Meteors are the streaks of light caused by meteoroids as they burn up in Earth's atmosphere.*

Types of Meteorites

Like their asteroid relatives, meteorites have different compositions. The three major types of meteorites—stony, metallic, and stony-iron meteorites—are shown in **Figure 5.** Many of the stony meteorites probably come from carbon-rich asteroids. Stony meteorites may contain organic materials and water. Scientists use meteorites to study the early solar system. Like comets and asteroids, meteorites are some of the building blocks of planets.

Reading Check **What are the major types of meteorites?**

Figure 5 **Three Major Types of Meteorites**

Stony meteorite	**Metallic meteorite**	**Stony-iron meteorite**
rocky material	iron and nickel	rocky material, iron, and nickel

Copyright © by Holt, Rinehart and Winston. All rights reserved.

The Role of Impacts in the Solar System

An impact happens when an object in space collides with another object in space. Often, the result of such a collision is an impact crater. Many planets and moons have visible impact craters. In fact, several planets and moons have many more impact craters than Earth does. Planets and moons that do not have atmospheres have more impact craters than do planets and moons that have atmospheres.

Look at **Figure 6.** Earth's moon has many more impact craters than the Earth does because the moon has no atmosphere to slow objects down. Fewer objects strike Earth because Earth's atmosphere acts as a shield. Smaller objects burn up before they ever reach the surface. Also, most craters left on Earth are no longer visible because of weathering, erosion, and tectonic activity.

CONNECTION TO Biology

WRITING SKILL **Mass Extinctions** Throughout Earth's history, there have been times when large numbers of species suddenly became extinct. Many scientists think that these mass extinctions may have been caused by impacts of large objects on Earth. However, other scientists are not so sure. Use the Internet or another source to research this idea. In your **science journal,** write a paragraph describing the different theories scientists have for past mass extinctions.

Future Impacts on Earth?

Most objects that come close to Earth are small and usually burn up in the atmosphere. However, larger objects are more likely to strike Earth's surface. Scientists estimate that impacts that are powerful enough to cause a natural disaster might happen once every few thousand years. An impact that is large enough to cause a global catastrophe is estimated to happen once every few hundred thousand years, on average.

Reading Check **How often do large objects strike Earth?**

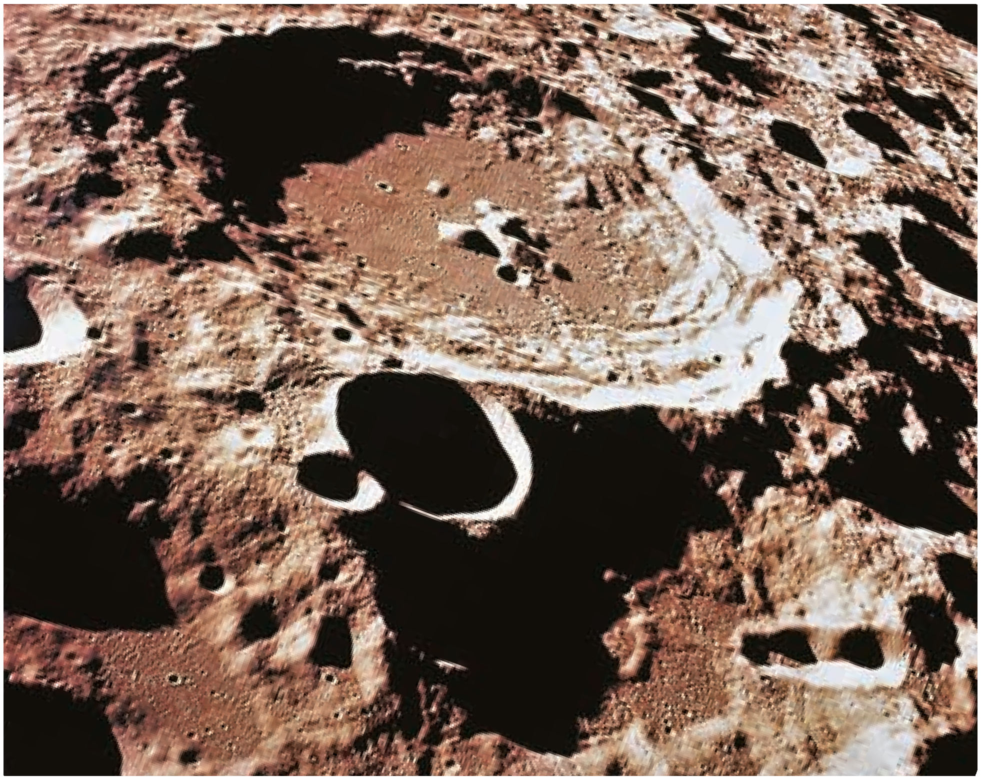


Figure 6 *The surface of the moon preserves a record of billions of years of cosmic impacts.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

The Torino Scale

The Torino scale is a system that allows scientists to rate the hazard level of an object moving toward Earth. The object is carefully observed and then assigned a number from the scale. The scale ranges from 0 to 10. Zero indicates that the object has a very small chance of striking Earth. Ten indicates that the object will definitely strike Earth and cause a global disaster. The Torino scale is also color coded. White represents 0, and green represents 1. White and green objects rarely strike Earth. Yellow represents 2, 3, and 4 and indicates a higher chance that objects will hit Earth. Orange, which represents 5, 6, and 7, refers to objects highly likely to hit Earth. Red refers to objects that will definitely hit Earth.

SECTION Review

Summary

- Studying comets, asteroids, and meteoroids can help scientists understand more about the formation of the solar system.
- Asteroids are small bodies that orbit the sun. Meteoroids are similar to but smaller than asteroids. Most meteoroids come from asteroids.
- Most objects that collide with Earth burn up in the atmosphere. Large impacts, however, may cause a global catastrophe.

Using Key Terms

For each pair of terms, explain how the meanings of the terms differ.

1. *comet* and *asteroid*
2. *meteor* and *meteorite*

Understanding Key Ideas

3. Which of the following is NOT a type of meteorite?
   a. stony meteorite
   b. rocky-iron meteorite
   c. stony-iron meteorite
   d. metallic meteorite
4. Why is the study of comets, asteroids, and meteoroids important in understanding the formation of the solar system?
5. Why do a comet's two tails often point in different directions?
6. How can a cosmic impact affect life on Earth?
7. What is the difference between an asteroid and a meteoroid?
8. Where is the asteroid belt located?
9. What is the Torino scale?
10. Describe why we see several impact craters on the moon but few on Earth.

Math Skills

11. The diameter of comet A's nucleus is 55 km. If the diameter of comet B's nucleus is 30% larger than comet A's nucleus, what is the diameter of comet B's nucleus?

Critical Thinking

12. **Expressing Opinions** Do you think the government should spend money on programs to search for asteroids and comets that have Earth-crossing orbits? Explain.
13. **Making Inferences** What is the likelihood that scientists will discover an object belonging in the red category of the Torino scale in the next 500 years? Explain your answer.

SCILINKS® NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Comets, Asteroids, and Meteoroids

SciLinks code: HSM0317

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Using Scientific Methods

Inquiry Lab

Create a Calendar

OBJECTIVES

Create a calendar based on the Martian cycles of rotation and revolution.

Describe why it is useful to have a calendar that matches the cycles of the planet on which you live.

MATERIALS

- calculator (optional)
- marker
- pencils, assorted colors
- poster board
- ruler, metric

Imagine that you live in the first colony on Mars. You have been trying to follow the Earth calendar, but it just isn't working anymore. Mars takes almost 2 Earth years to revolve around the sun—almost 687 Earth days to be exact! That means that there are only two Martian seasons for every Earth calendar year. On Mars, in one Earth year, you get winter and spring, but the next year, you get only summer and fall! And Martian days are longer than Earth days. Mars takes 24.6 Earth hours to rotate on its axis. Although they are similar, Earth days and Martian days just don't match. You need a new calendar!

Ask a Question

1. How can I create a calendar based on the Martian cycles of rotation and revolution that includes months, weeks, and days?

Form a Hypothesis

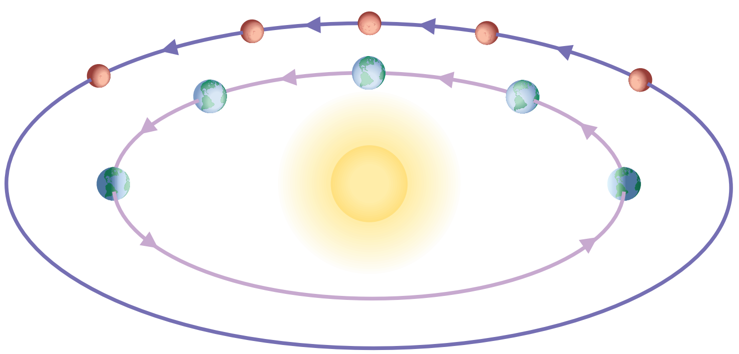
2. Write a few sentences that answer your question.

Test the Hypothesis

3. Use the following formulas to determine the number of Martian days in a Martian year:

$$\frac{687 \text{ Earth days}}{1 \text{ Martian year}} \times \frac{24 \text{ Earth hours}}{1 \text{ Earth day}} = \text{Earth hours per Martian year}$$

$$\text{Earth hours per Martian year} \times \frac{1 \text{ Martian day}}{24.6 \text{ Earth hours}} = \text{Martian days per Martian year}$$



Copyright © by Holt, Rinehart and Winston. All rights reserved.

4. Decide how to divide your calendar into a system of Martian months, weeks, and days. Will you have a leap day, a leap week, a leap month, or a leap year? How often will it occur?
5. Choose names for the months and days of your calendar. Explain why you chose each name. If you have time, explain how you would number the Martian years. For instance, would the first year correspond to a certain Earth year?
6. Follow your design to create your own calendar for Mars. Construct your calendar by using a computer to help organize your data. Draw the calendar on your piece of poster board. Make sure it is brightly colored and easy to follow.
7. Present your calendar to the class. Explain how you chose your months, weeks, and days.

Analyze the Results

1. **Analyzing Results** What advantages does your calendar design have? Are there any disadvantages to your design?
2. **Classifying** Which student or group created the most original calendar? Which design was the most useful? Explain.
3. **Analyzing Results** What might you do to improve your calendar?

Draw Conclusions

4. **Evaluating Models** Take a class vote to decide which design should be chosen as the new calendar for Mars. Why was this calendar chosen? How did it differ from the other designs?
5. **Drawing Conclusions** Why is it useful to have a calendar that matches the cycles of the planet on which you live?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Chapter Review

USING KEY TERMS

For each pair of terms, explain how the meanings of the terms differ.

1. *terrestrial planet* and *gas giant*
2. *asteroid* and *comet*
3. *meteor* and *meteorite*

Complete each of the following sentences by choosing the correct term from the word bank.

astronomical unit	meteorite
meteoroid	prograde
retrograde	satellite

4. The average distance between the sun and Earth is 1 ___.
5. A small rock in space is called a(n) ___.
6. When viewed from above its north pole, a body that moves in a counterclockwise direction is said to have ___ rotation.
7. A(n) ___ is a natural or artificial body that revolves around a planet.

UNDERSTANDING KEY IDEAS

Multiple Choice

8. Of the following, which is the largest body?
   a. the moon
   b. Pluto
   c. Mercury
   d. Ganymede

9. Which of the following planets have retrograde rotation?
   a. the terrestrial planets
   b. the gas giants
   c. Mercury, Venus, and Uranus
   d. Venus, Uranus, and Pluto

10. Which of the following planets does NOT have any moons?
    a. Mercury
    b. Mars
    c. Uranus
    d. None of the above

11. Why can liquid water NOT exist on the surface of Mars?
    a. The temperature is too high.
    b. Liquid water once existed there.
    c. The gravity of Mars is too weak.
    d. The atmospheric pressure is too low.

Short Answer

12. List the names of the planets in the order the planets orbit the sun.
13. Describe three ways in which the inner planets are different from the outer planets.
14. What are the gas giants? How are the gas giants different from the terrestrial planets?
15. What is the difference between asteroids and meteoroids?
16. What is the difference between a planet's period of rotation and period of revolution?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

17 Explain the difference between prograde rotation and retrograde rotation.

18 Which characteristics of Earth make it suitable for life?

19 Scientists estimate that an impact causing a natural disaster will happen how often?

20 What are the Galilean satellites?

CRITICAL THINKING

21 **Concept Mapping** Use the following terms to create a concept map: *solar system, terrestrial planets, gas giants, moons, comets, asteroids,* and *meteoroids*.

22 **Applying Concepts** Even though we haven't yet retrieved any rock samples from Mercury's surface for radiometric dating, scientists know that the surface of Mercury is much older than that of Earth. How do scientists know this?

23 **Making Inferences** Where in the solar system might scientists search for life, and why?

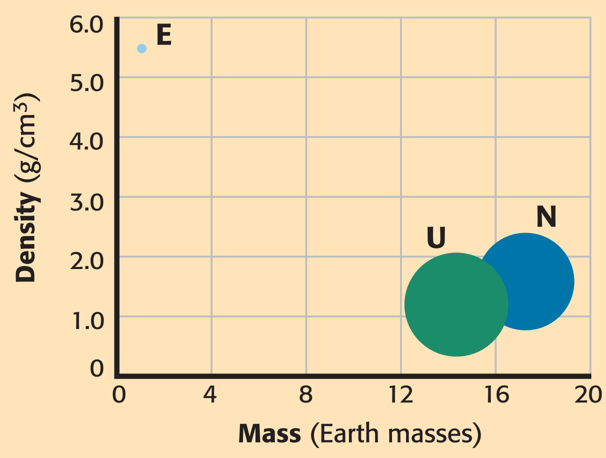
24 **Predicting Consequences** If scientists could somehow bring Europa as close to the sun as the Earth is, 1 AU, how do you think Europa would be affected?

25 **Identifying Relationships** How did variations in the orbit of Uranus help scientists discover Neptune?

INTERPRETING GRAPHICS

The graph below shows density versus mass for Earth, Uranus, and Neptune. Mass is given in Earth masses—the mass of Earth is equal to 1 Earth mass. The relative volumes for the planets are shown by the size of each circle. Use the graph below to answer the questions that follow.

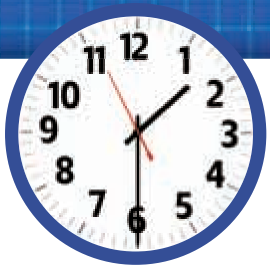
Density Vs. Mass for Earth, Uranus, and Neptune



26 Which planet is denser, Uranus or Neptune? How can you tell?

27 You can see that although Earth has the smallest mass, it has the highest density of the three planets. How can Earth be the densest of the three when Uranus and Neptune have so much more mass than Earth does?

Copyright © by Holt, Rinehart and Winston. All rights reserved.



Standardized Test Preparation

EOG Prep

READING

Read each of the passages below. Then, answer the questions that follow each passage.

Passage 1 Imagine that it is 200 BCE and you are an apprentice to a Greek astronomer. After years of observing the sky, the astronomer knows all of the constellations as well as the back of his hand. He shows you how the stars all move together—the whole sky spins slowly as the night goes on. He also shows you that among the thousands of stars in the sky, some of the brighter ones slowly change their position relative to the other stars. He names these stars *planetai*, the Greek word for "wanderers." Building on the observations of the ancient Greeks, we now know that the *planetai* are actually planets, not wandering stars.

1. Which of the following did the ancient Greeks know to be true?

A All planets have at least one moon.
B The planets revolve around the sun.
C The planets are much smaller than the stars.
D The planets appear to move relative to the stars.

2. What can you infer from the passage about the ancient Greek astronomers?

F They were patient and observant.
G They knew much more about astronomy than we do.
H They spent all their time counting stars.
I They invented astrology.

3. What does the word *planetai* mean in Greek?

A planets
B wanderers
C stars
D moons

Passage 2 To explain the source of short-period comets (comets that have a relatively short orbit), the Dutch-American astronomer Gerard Kuiper proposed in 1949 that a belt of icy bodies must lie beyond the orbits of Pluto and Neptune. Kuiper argued that comets were icy planetesimals that formed from the condensation that happened during the formation of our galaxy. Because the icy bodies are so far from any large planet's gravitational field (30 to 100 AU), they can remain on the fringe of the solar system. Some theorists speculate that the large moons Triton and Charon were once members of the Kuiper belt before they were captured by Neptune and Pluto. These moons and short-period comets have similar physical and chemical properties.

1. According to the passage, why can icy bodies remain at the edge of the solar system?

A The icy bodies are so small that they naturally float to the edge of the solar system.
B The icy bodies have weak gravitational fields and therefore do not orbit individual planets.
C The icy bodies are short-period comets, which can reside only at the edge of the solar system.
D The icy bodies are so far away from any large planet's gravitational field that they can remain at the edge of the solar system.

2. According to the passage, which of the following best describes the meaning of the word *planetesimal*?

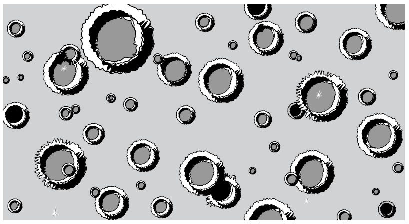
F a small object that existed during the early development of the solar system
G an extremely tiny object in space
H a particle that was once part of a planet
I an extremely large satellite that was the result of a collision of two objects

Copyright © by Holt, Rinehart and Winston. All rights reserved.

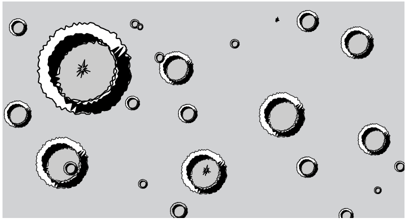
INTERPRETING GRAPHICS

Use the diagrams below to answer the questions that follow.

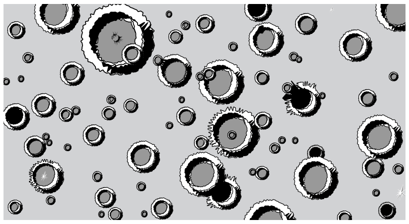
Planet A 115 craters/km²



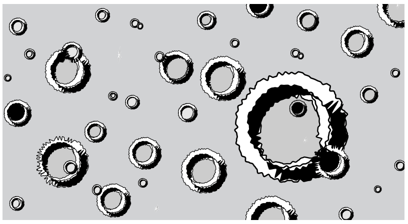
Planet B 75 craters/km²



Planet C 121 craters/km²



Planet D 97 craters/km²



1. According to the information above, which planet has the oldest surface?

A planet A
B planet B
C planet C
D planet D

2. How many more craters per square kilometer are there on planet C than on planet B?

F 46 craters per square kilometer
G 24 craters per square kilometer
H 22 craters per square kilometer
I 6 craters per square kilometer

MATH

Read each question below, and choose the best answer.

1. Venus's surface gravity is 91% of Earth's. If an object weighs 12 N on Earth, how much would it weigh on Venus?

A 53 N
B 13 N
C 11 N
D 8 N

2. Earth's overall density is 5.52 g/cm^3, while Saturn's density is 0.69 g/cm^3. How many times denser is Earth than Saturn?

F 8 times
G 9 times
H 11 times
I 12 times

3. If Earth's history spans 4.6 billion years and the Phanerozoic eon was 543 million years, what percentage of Earth's history does the Phanerozoic eon represent?

A about 6%
B about 12%
C about 18%
D about 24%

4. The diameter of Venus is 12,104 km. The diameter of Mars is 6,794 km. What is the difference between the diameter of Venus and the diameter of Mars?

F 5,400 km
G 5,310 km
H 4,890 km
I 890 km

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Science in Action

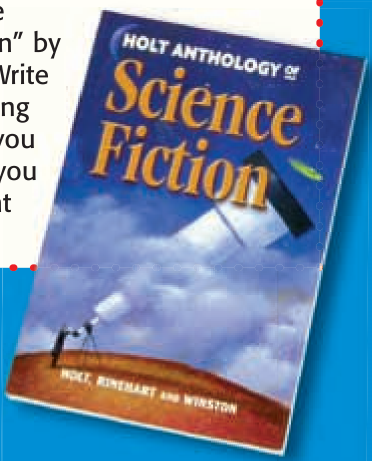
Science Fiction

"The Mad Moon" by Stanley Weinbaum

The third largest moon of Jupiter, called Io, can be a hard place to live. Grant Calthorpe is finding this out the hard way. Although living comfortably is possible in the small cities at the polar regions of Io, Grant has to spend most of his time in the moon's hot and humid jungles. Grant treks into the jungles of Io to gather ferva leaves so that they can be converted into useful medications for humans. During Grant's quest, he encounters loonies and slinkers, and he has to avoid blancha, a kind of tropical fever that causes hallucinations, weakness, and vicious headaches. Without proper medication a person with blancha can go mad or even die. In "The Mad Moon," you'll discover a dozen adventures with Grant Calthorpe as he struggles to stay alive—and sane.

Language Arts ACTIVITY

WRITING SKILL Read "The Mad Moon" by Stanley Weinbaum. Write a short story describing the adventures that you would have on Io if you were chosen as Grant Calthorpe's assistant.



Scientific Debate

Is Pluto a Planet?

Is it possible that Pluto isn't a planet? Some scientists think so! Since 1930, Pluto has been included as one of the nine planets in our solar system. But observations in the 1990s led many astronomers to refer to Pluto as an object, not a planet. Other astronomers disagree with this change. Astronomers that refer to Pluto as an object do not think that it fits well with the other outer planets. Unlike the other outer planets, which are large and gaseous, Pluto is small and made of rock and ice. Pluto also has a very elliptical orbit that is unlike its neighboring planets. Astronomers that think Pluto is a planet point out that Pluto, like all other planets, has its own atmosphere and its own moon, called Charon. These and other factors have fueled a debate as to whether Pluto should be classified as a planet.

Math ACTIVITY

How many more kilometers is Earth's diameter compared to Pluto's diameter if Earth's diameter is 12,756 km and Pluto's diameter is 2,390 km?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Careers

Adriana C. Ocampo

Planetary Geologist Sixty-five million years ago, in what is now Mexico, a giant meteor at least six miles wide struck Earth. The meteor made a hole nine miles deep and over 100 miles wide. The meteor sent billions of tons of dust into Earth's atmosphere. This dust formed thick clouds. After forming, these clouds may have left the planet in total darkness for six months, and the temperature near freezing for ten years. Some scientists think that this meteor crash and its effect on the Earth's climate led to the extinction of the dinosaurs. Adriana Ocampo studies the site in Mexico made by the crater known as the Chicxulub (cheeks OO loob) impact crater. Ocampo is a planetary geologist and has been interested in space exploration since she was young. Ocampo's specialty is studying "impact craters." "Impact craters are formed when an asteroid or a comet collides with the Earth or any other terrestrial planet," explains Ocampo. Ocampo visits crater sites around the world to collect data. She also uses computers to create models of how the impact affected the planet. Ocampo has worked for NASA and has helped plan space exploration missions to Mars, Jupiter, Saturn, and Mercury. Ocampo currently works for the European Space Agency (ESA) and is part of the team getting ready to launch the next spacecraft that will go to Mars.

Social Studies ACTiViTY

Research information about impact craters. Find the different locations around the world where impact craters have been found. Make a world map that highlights these locations.

The circle on the map shows the site in Mexico made by the Chicxulub impact crater.

To learn more about these Science in Action topics, visit **go.hrw.com** and type in the keyword **HZ5FAMF.**

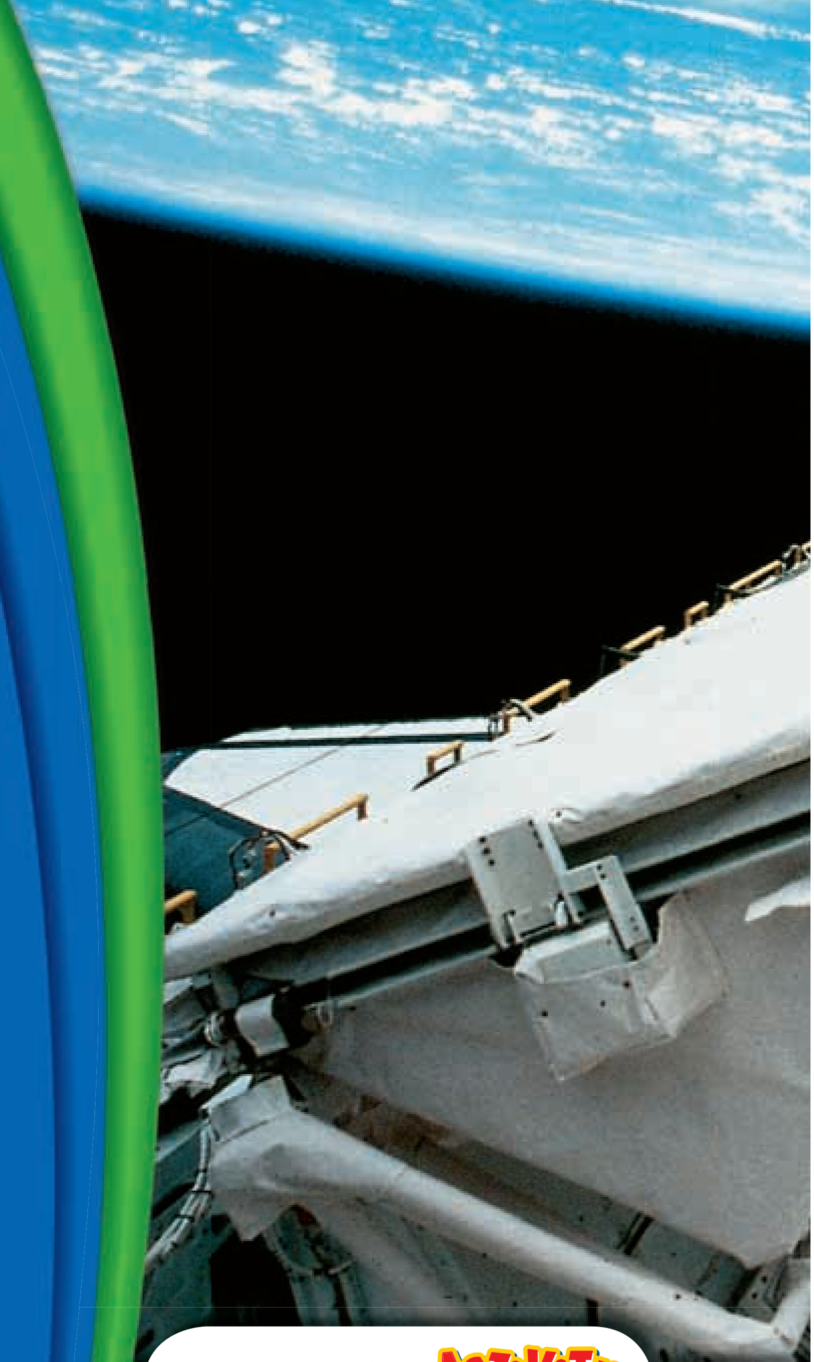
Current Science

Check out Current Science® articles related to this chapter by visiting go.hrw.com. Just type in the keyword HZ5CS21.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

12

Exploring Space



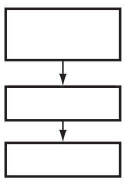
About the PHOTO

Although the astronauts in the photo appear to be motionless, they are orbiting the Earth at almost 28,000 km/h! The astronauts reached orbit—about 300 km above the Earth's surface—in a space shuttle. Space shuttles are the first vehicles in a new generation of reusable spacecraft. They have opened an era of space exploration in which missions to space are more common than ever before.

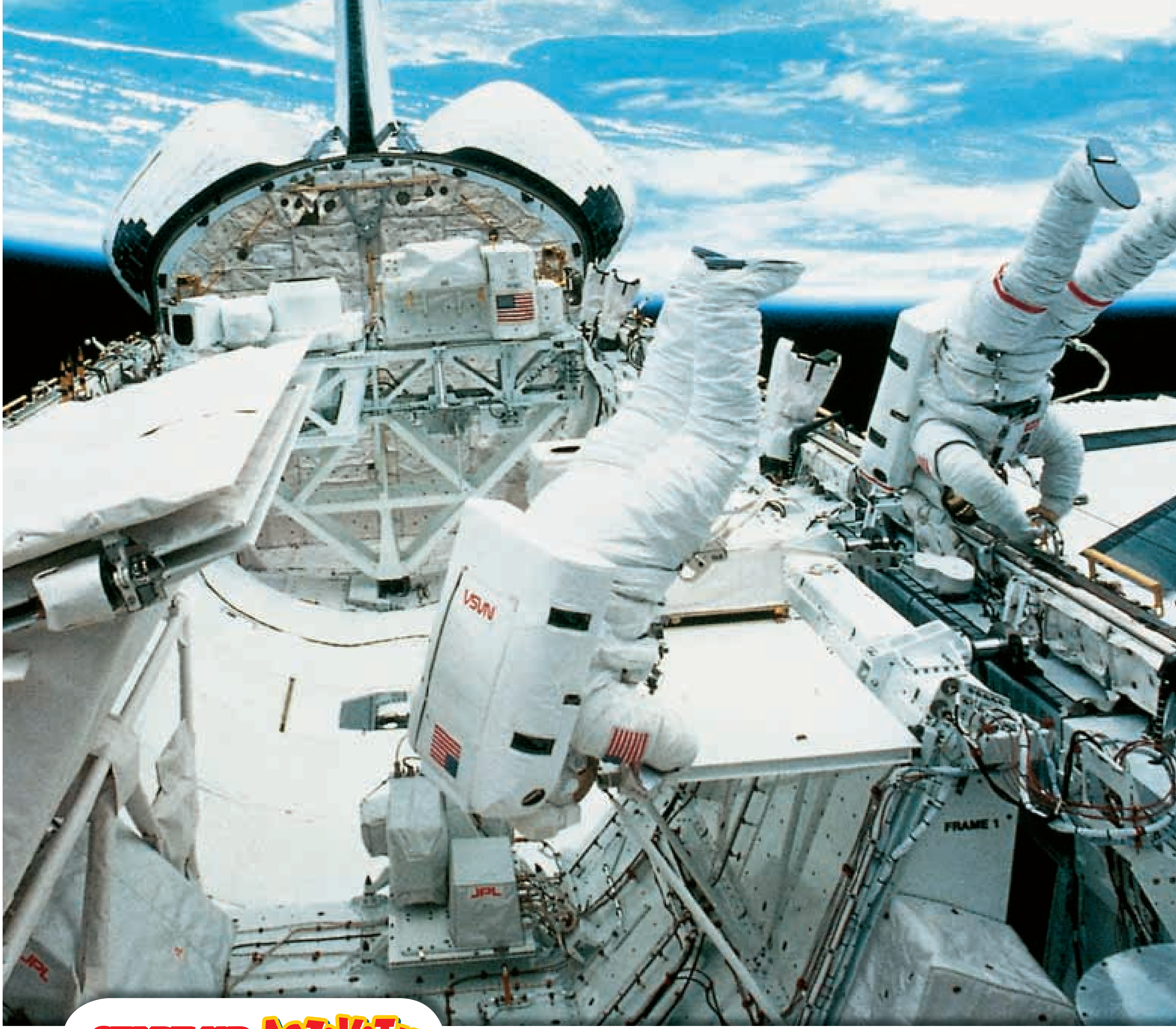
PRE-READING ACTIVITY

Graphic Organizer

Chain-of-Events Chart Before you read the chapter, create the graphic organizer entitled "Chain-of-Events Chart" described in the **Study Skills** section of the Appendix. As you read the chapter, fill in the chart with a timeline that describes the exploration of space from the theories of Konstantin Tsiolkovsky to the future of space exploration.



Copyright © by Holt, Rinehart and Winston. All rights reserved.



START-UP ACTIVITY

Balloon Rockets

In this activity you will launch a balloon "rocket" to learn about how rockets move.

Procedure

1. Insert a **2 m thread** through a **drinking straw,** and tie it between two objects that won't move, such as **chairs.** Make sure that the thread is tight.
2. Inflate a **large balloon.** Do not tie the neck of the balloon closed. Hold the neck of the balloon closed, and **tape** the balloon firmly to the straw, parallel to the thread.
3. Move the balloon to one end of the thread, and then release the neck of the balloon. Use a **meter-stick** to record the distance the balloon traveled.
4. Repeat steps 2–3. This time, hold a piece of **poster board** behind the balloon.

Analysis

1. Did the poster board affect the distance that the balloon traveled? Explain your answer.
2. Newton's third law of motion states that for every action there is an equal and opposite reaction. Apply this idea and your observations of the balloon to explain how rockets accelerate. Do rockets move by "pushing off" a launch pad? Explain your answer.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 1

Rocket Science

If you could pack all of your friends in a car and drive to the moon, it would take about 165 days to get there. And that doesn't include stopping for gas or food!

READING WARM-UP

Objectives

- Outline the development of rocket technology.
- Describe how a rocket accelerates.
- Explain the difference between orbital velocity and escape velocity.

Terms to Learn

rocket
thrust
NASA

READING STRATEGY

Discussion Read this section silently. Write down questions that you have about this section. Discuss your questions in a small group.

The moon is incredibly far away, and years ago people could only dream of traveling into space. The problem was that no machine could generate enough force to overcome Earth's gravity and reach outer space. But about 100 years ago, a Russian high school teacher named Konstantin Tsiolkovsky (KAHN stuhn TEEN TSI uhl KAHV skee) proposed that machines called *rockets* could take people to outer space. A **rocket** is a machine that uses escaping gas to move. Tsiolkovsky stated, "The Earth is the cradle of mankind. But one does not have to live in the cradle forever." Rockets would become the key to leaving the cradle of Earth and starting the age of space exploration.

The Beginnings of Rocket Science

Tsiolkovsky's inspiration came from the imaginative stories of Jules Verne. In Verne's book *From the Earth to the Moon,* characters reached the moon in a capsule shot from an enormous cannon. Although this idea would not work, Tsiolkovsky proved—in theory—that rockets could generate enough force to reach outer space. He also suggested the use of liquid rocket fuel to increase a rocket's range. For his vision and careful work, Tsiolkovsky is known as the father of rocket theory.

Figure 1 *Robert Goddard is known as the father of modern rocketry.*

A Boost for Modern Rocketry

Although Tsiolkovsky proved scientifically that rockets could reach outer space, he never built any rockets himself. That task was left to American physicist and inventor Robert Goddard, shown in **Figure 1.** Goddard launched the first successful liquid-fuel rocket in 1926. Goddard tested more than 150 rocket engines, and by the time of World War II, Goddard's work began to interest the United States military. His work drew much attention because of a terrifying new weapon that the German army had developed.

Reading Check **How did Tsiolkovsky and Goddard contribute to the development of rockets?** (*See the Appendix for answers to Reading Checks.*)

Copyright © by Holt, Rinehart and Winston. All rights reserved.

From Rocket Bombs to Rocket Ships

Figure 2 *The V-2 rocket is the ancestor of all modern rockets.*

Toward the end of World War II, Germany developed a new weapon known as the V-2 rocket. The V-2 rocket, shown in **Figure 2,** could deliver explosives from German military bases to London—a distance of about 350 km. The V-2 rocket was developed by a team led by Wernher von Braun, a young Ph.D. student whose research was supported by the German military. But in 1945, near the end of the war, von Braun and his entire research team surrendered to the advancing Americans. The United States thus gained 127 of the best German rocket scientists. With this gain, rocket research in the United States boomed in the 1950s.

The Birth of NASA

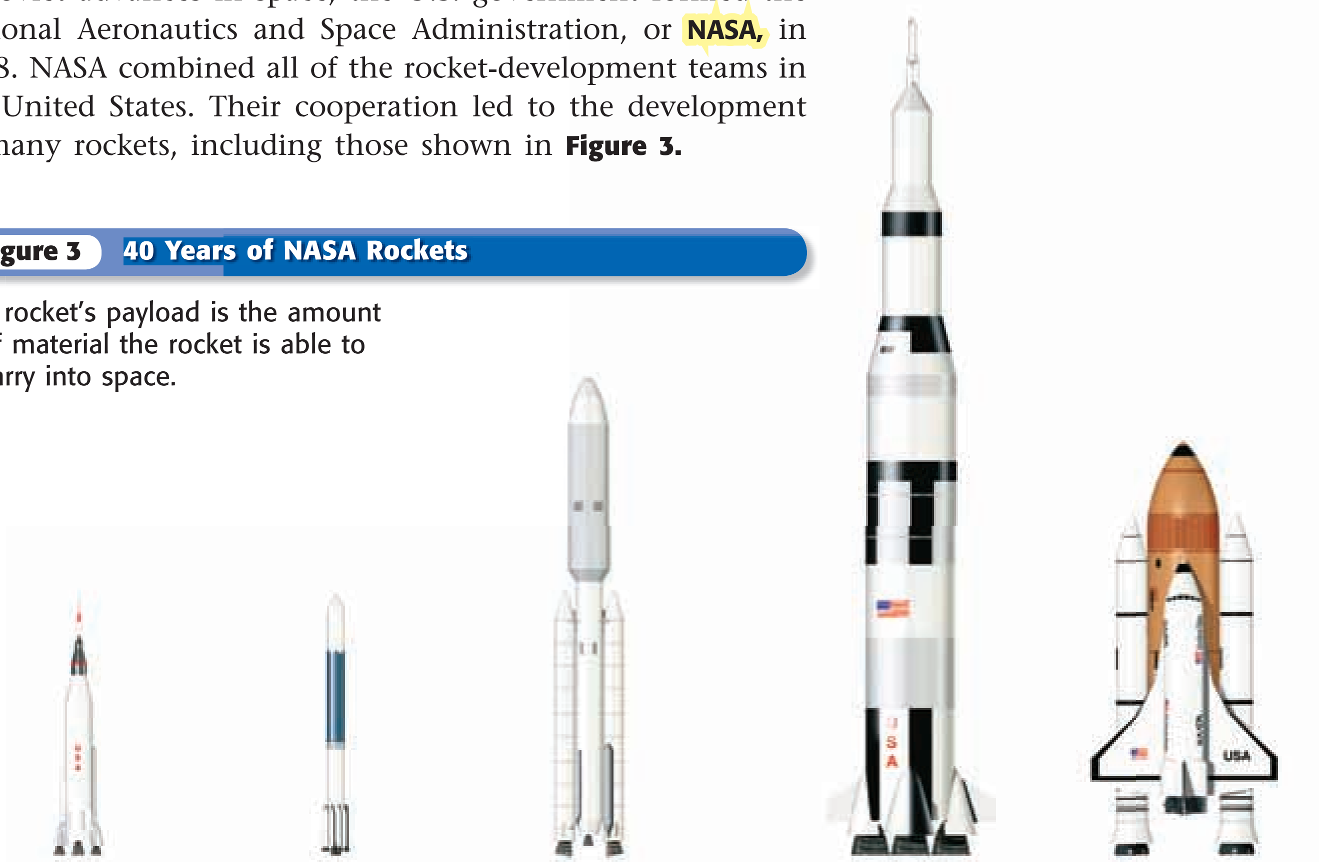
The end of World War II marked the beginning of the *Cold War*—a long period of political tension between the United States and the Soviet Union. The Cold War was marked by an arms race and by competition in space technology. In response to Soviet advances in space, the U.S. government formed the National Aeronautics and Space Administration, or **NASA,** in 1958. NASA combined all of the rocket-development teams in the United States. Their cooperation led to the development of many rockets, including those shown in **Figure 3.**

rocket a machine that uses escaping gas from burning fuel to move

NASA the **N**ational **A**eronautics and **S**pace **A**dministration

Figure 3 **40 Years of NASA Rockets**

A rocket's payload is the amount of material the rocket is able to carry into space.



Mercury-Atlas	Delta	Titan IV	Saturn V	Space shuttle and boosters
Height: 29 m	**Height:** 36 m	**Height:** 62 m	**Height:** 111 m	**Height:** 56 m
Payload: 1,400 kg	**Payload:** 1,770 kg	**Payload:** 18,000 kg	**Payload:** 129,300 kg	**Payload:** 29,500 kg

Copyright © by Holt, Rinehart and Winston. All rights reserved.

thrust the pushing or pulling force exerted by the engine of an aircraft or rocket

How Rockets Work

If you are sitting in a chair that has wheels and you want to move, you would probably push away from a table or kick yourself along with your feet. Many people think that rockets move in a similar way—by pushing off of a launch pad. But if rockets moved in this way, how would they accelerate in the vacuum of space where there is nothing to push against?

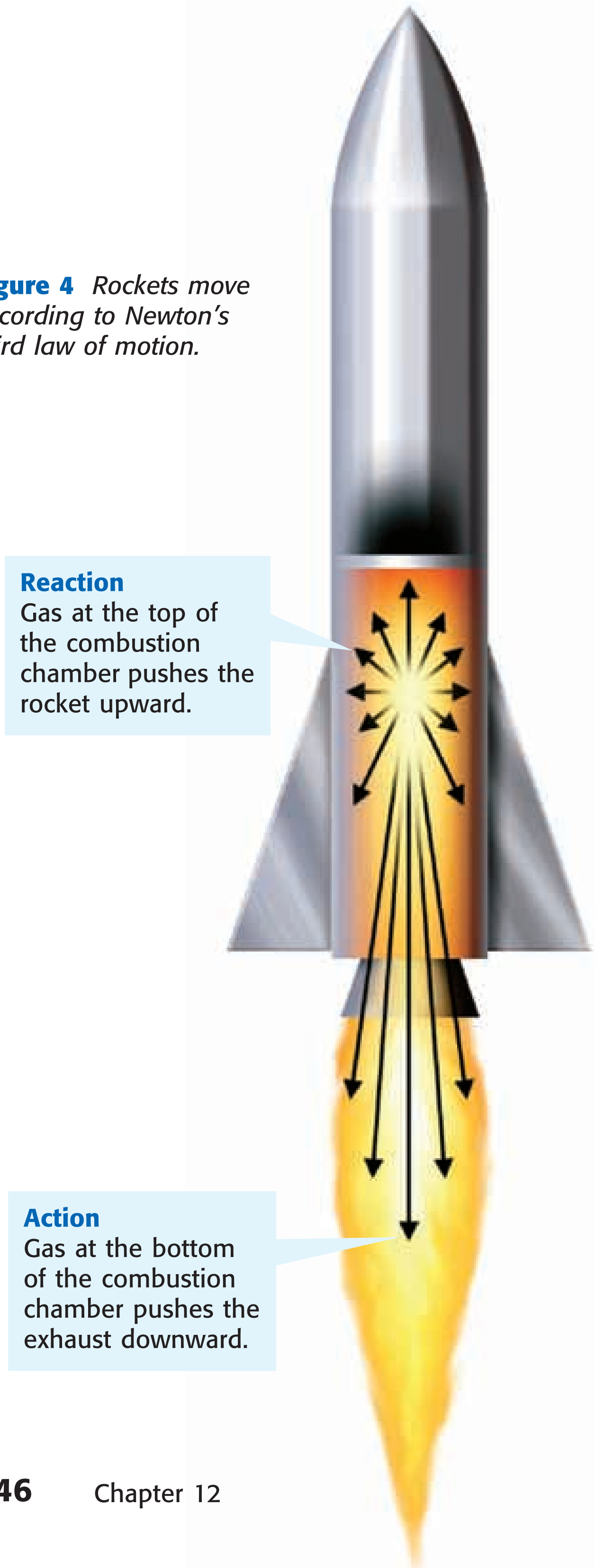


Figure 4 *Rockets move according to Newton's third law of motion.*

For Every Action . . .

As you saw in the Start-Up Activity, the balloon moved according to Newton's third law of motion. This law states that for every action there is an equal and opposite reaction. For example, the air rushing backward from a balloon (the action) results in the forward motion of the balloon (the reaction). Rockets work in the same way. In fact, rockets were once called *reaction devices*.

However, in the case of rockets, the action and the reaction may not be obvious. The mass of a rocket—including all of the fuel it carries—is much greater than the mass of the hot gases that come out of the bottom of the rocket. But because the exhaust gases are under extreme pressure, they exert a huge amount of force. The force that accelerates a rocket is called **thrust.** Look at **Figure 4** to learn more about how rockets work.

You Need More Than Rocket Fuel

Rockets burn fuel to provide the thrust that propels them. In order for something to burn, oxygen must be present. Although oxygen is plentiful at the Earth's surface, there is little or no oxygen in the upper atmosphere and in outer space. For this reason, rockets that go into outer space must carry enough oxygen with them to be able to burn their fuel. The space shuttles, for example, carry hundreds of thousands of gallons of liquid oxygen. This oxygen is needed to burn the shuttle's rocket fuel.

Reading Check **Why do rockets carry oxygen in addition to fuel?**

Copyright © by Holt, Rinehart and Winston. All rights reserved.

How to Leave the Earth

The gravitational pull of the Earth is the main factor that a rocket must overcome. As shown in **Figure 5,** a rocket must reach a certain *velocity*, or speed and direction, to orbit or escape the Earth.

Orbital Velocity and Escape Velocity

For a rocket to orbit the Earth, it must have enough thrust to reach orbital velocity. *Orbital velocity* is the speed and direction a rocket must travel in order to orbit a planet or moon. The lowest possible speed a rocket may go and still orbit the Earth is about 8 km/s (17,927 mi/h). If the rocket goes any slower, it will fall back to Earth. For a rocket to travel beyond Earth orbit, the rocket must achieve escape velocity. *Escape velocity* is the speed and direction a rocket must travel to completely break away from a planet's gravitational pull. The speed a rocket must reach to escape the Earth is about 11 km/s (24,606 mi/h).

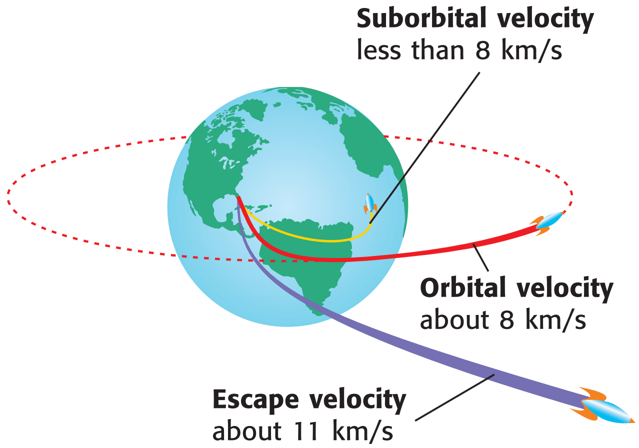


Figure 5 *A rocket must travel very fast to escape the gravitational pull of the Earth.*

SECTION Review

Summary

- Tsiolkovsky and Goddard were pioneers of rocket science.
- The outcome of WWII and the political pressures of the Cold War helped advance rocket science.
- Rockets work according to Newton's third law of motion—for every action there is an equal and opposite reaction.
- Rockets need to reach different velocities to attain orbit and to escape a planet's gravitational attraction.

Using Key Terms

1. Use each of the following terms in a separate sentence: *rocket, thrust,* and *NASA.*

Understanding Key Ideas

2. What factor must a rocket overcome to reach escape velocity?
   a. Earth's axial tilt
   b. Earth's gravity
   c. the thrust of its engines
   d. Newton's third law of motion
3. Describe the contributions of Tsiolkovsky and Goddard to modern rocketry.
4. Use Newton's third law of motion to describe how rockets work.
5. What is the difference between orbital and escape velocity?
6. How did the Cold War accelerate the U.S. space program?

Math Skills

7. If you travel at 60 mi/h, it takes about 165 days to reach the moon. Approximately how far away is the moon?

Critical Thinking

8. **Applying Concepts** How do rockets accelerate in space?
9. **Making Inferences** Why does escape velocity vary depending on the planet from which a rocket is launched?

SCILINKS® NSTA
Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Rocket Technology
SciLinks code: HSM1323

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 2

Artificial Satellites

You are watching TV, and suddenly a weather bulletin interrupts your favorite show. There is a HURRICANE WARNING! You grab a cell phone and call your friend—the hurricane is headed straight for where she lives!

READING WARM-UP

Objectives

- Identify the first satellites.
- Compare low Earth orbits with geostationary orbits.
- Explain the functions of military, communications, and weather satellites.
- Explain how remote sensing from satellites has helped us study Earth as a global system.

Terms to Learn

artificial satellite
low Earth orbit
geostationary orbit

READING STRATEGY

Reading Organizer As you read this section, make a table comparing the advantages and disadvantages of low Earth orbits and geostationary orbits.

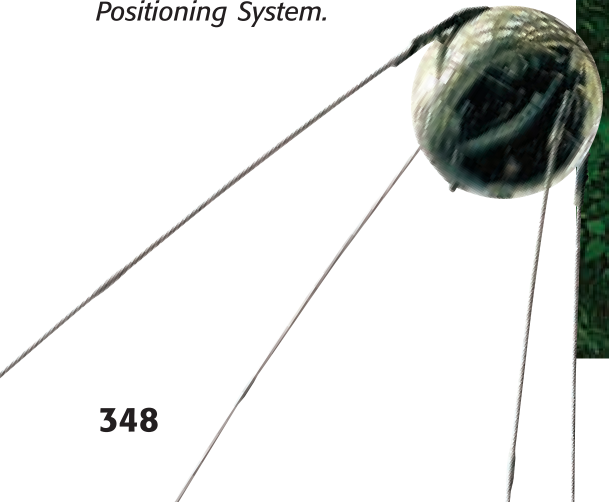
In the story above, the TV show, the weather bulletin, and perhaps even the phone call were all made possible by artificial satellites orbiting thousands of miles above Earth! An **artificial satellite** is any human-made object placed in orbit around a body in space.

There are many kinds of artificial satellites. Weather satellites provide continuous updates on the movement of gases in the atmosphere so that we can predict weather on Earth's surface. Communications satellites relay TV programs, phone calls, and computer data. Remote-sensing satellites monitor changes in the environment. Perhaps more than the exploration of space, satellites have changed the way we live.

The First Satellites

The first artificial satellite, *Sputnik 1,* was launched by the Soviets in 1957. **Figure 1** shows a model of *Sputnik 1,* which orbited for 57 days before it fell back to Earth and burned up in the atmosphere. Two months later, *Sputnik 2* carried the first living being into space—a dog named Laika. The United States followed with the launch of its first satellite, *Explorer 1,* in 1958. The development of new satellites increased quickly. By 1964, communications satellite networks were able to send messages around the world. Today, thousands of satellites orbit the Earth, and more are launched every year.

Figure 1 *A model of* Sputnik 1, *the first satellite to orbit the Earth, is shown below. It started a revolution in modern life that led to technology such as the Global Positioning System.*



Copyright © by Holt, Rinehart and Winston. All rights reserved.

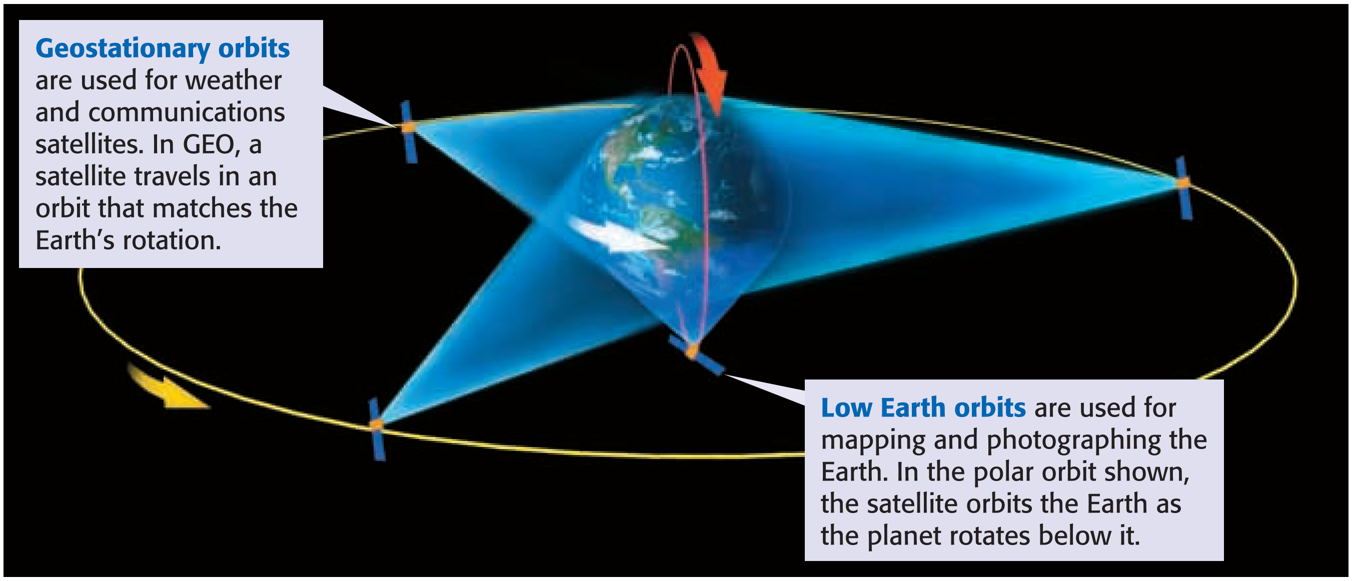


Figure 2 *Low Earth orbits are in the upper reaches of Earth's atmosphere, while geostationary orbits are about 36,000 km from Earth's surface.*

Choosing Your Orbit

Satellites are placed in different types of orbits, as shown in **Figure 2.** All of the early satellites were placed in **low Earth orbit** (LEO), which is a few hundred kilometers above the Earth's surface. A satellite in LEO moves around the Earth very quickly and can provide clear images of Earth. However, this motion can place a satellite out of contact much of the time.

Most communications satellites and weather satellites orbit much farther from Earth. In this orbit, called a **geostationary orbit** (GEO), a satellite travels in an orbit that exactly matches the Earth's rotation. Thus, the satellite is always above the same spot on Earth. Ground stations are in continuous contact with these satellites so that TV programs and other communications will not be interrupted.

Reading Check **What is the difference between GEO and LEO?** (*See the Appendix for answers to Reading Checks.*)

artificial satellite any human-made object placed in orbit around a body in space

low Earth orbit an orbit less than 1,500 km above the Earth's surface

geostationary orbit an orbit that is about 36,000 km above the Earth's surface and in which a satellite is above a fixed spot on the equator

Quick Lab

Modeling LEO and GEO

1. Use a **length of thread** to measure 300 km on the scale of a **globe.**
2. Use another **length of thread** to measure 36,000 km on the globe's scale.
3. Use the short thread to measure the distance of LEO from the surface of the globe and the long thread to measure the distance of GEO from the surface of the globe.
4. Your teacher will turn off the lights. One student will spin the globe, while other students will hold **penlights** at LEO and GEO orbits.
5. Was more of the globe illuminated by the penlights in LEO or GEO?
6. Which orbit is better for communications satellites? Which orbit is better for spy satellites?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Military Satellites

Some satellites placed in LEO are equipped with cameras that can photograph the Earth's surface in amazing detail. It is possible to photograph objects as small as this book from LEO. While photographs taken by satellites are now used for everything from developing real estate to tracking the movements of dolphins, the technology was first developed by the military. Because satellites can take very detailed photos from hundreds of kilometers above the Earth's surface, they are ideal for defense purposes. The United States and the Soviet Union developed satellites to spy on each other right up to the end of the Cold War. **Figure 3,** for example, is a photo of San Francisco taken by a Soviet spy satellite in 1989. Even though the Cold War is over, spy satellites continue to play an important role in the military defense of many countries.

The Global Positioning System

In the past, people invented very complicated ways to keep from getting lost. Now, for less than $100, people can find out their exact location on Earth by using a Global Positioning System (GPS) receiver. GPS is another example of military satellite technology that has become a part of everyday life. The GPS consists of 27 solar-powered satellites that continuously send radio signals to Earth. From the amount of time it takes the signals to reach Earth, the hand-held receiver can calculate its distance from the satellites. Using the distance from four satellites, a GPS receiver can determine a person's location with great accuracy.

MATH PRACTICE

Triangulation

GPS uses the principle of triangulation. To practice triangulation, use a drawing compass and a photocopy of a U.S. map that has a scale. Try to find a city that is 980 km from Detroit and Miami, and 950 km from Baltimore. For each city named, adjust the compass to the correct distance on the map's scale. Then, place the compass point on the city's location. Draw a circle with a radius equal to the given distance. Where do the circles overlap? Once you have solved this riddle, write one for a friend!

ACTIVITY

Figure 3 *This photo was taken in 1989 by a Soviet spy satellite in LEO about 220 km above San Francisco. Can you identify any objects on the ground?*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

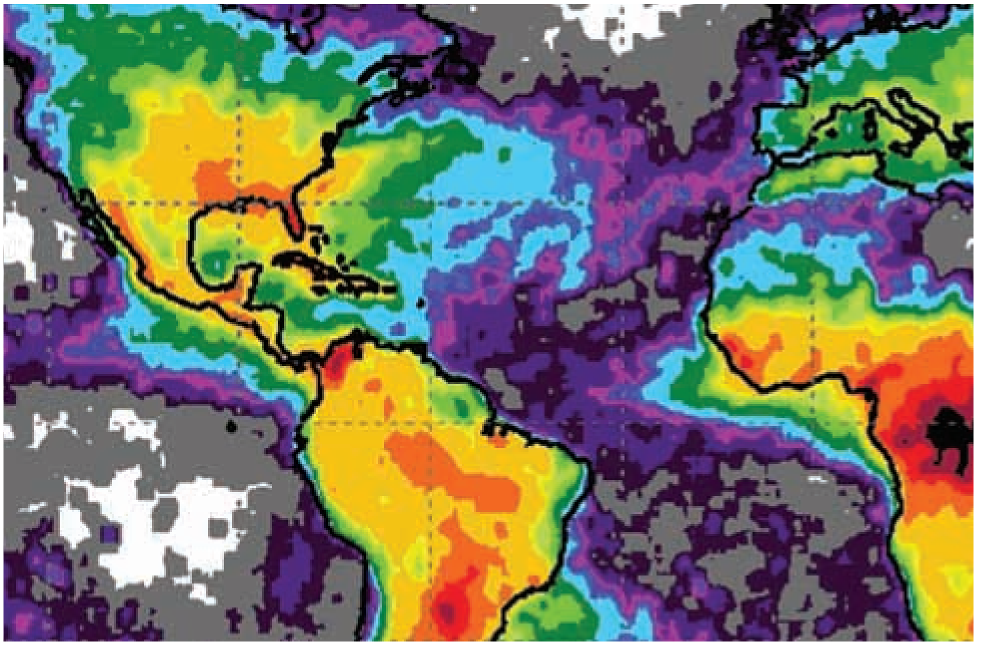


Figure 4 *This map shows average annual lightning strikes around the world. Red and black indicate a high number of strikes. Cooler colors, such as purple and blue, indicate fewer strikes.*

Weather Satellites

It is hard to imagine life without reliable weather forecasts. Every day, millions of people make decisions based on information provided by weather satellites. Weather satellites in GEO provide a big-picture view of the Earth's atmosphere. These satellites constantly monitor the atmosphere for the "triggers" that lead to severe weather conditions. Weather satellites in GEO created the map of world lightning strikes shown in **Figure 4.** Weather satellites in LEO are usually placed in polar orbits. Satellites in polar orbits revolve around the Earth in a north or south direction as the Earth rotates beneath them. These satellites, which orbit between 830 km and 870 km above the Earth, provide a much closer look at weather patterns.

Communications Satellites

Many types of modern communications use radio waves or microwaves to relay messages. Radio waves and microwaves are ideal for communications because they can travel through the air. The problem is that the Earth is round, but the waves travel in a straight line. So how do you send a message to someone on the other side of the Earth? Communications satellites in GEO solve this problem by relaying information from one point on Earth's surface to another. The signals are transmitted to a satellite and then sent to receivers around the world. Communications satellites relay computer data, and some television and radio broadcasts.

Reading Check **How do communications satellites relay information from one point on Earth's surface to another?**

SCHOOL to HOME

Tracking Satellites

A comfortable lawn chair and a clear night sky are all you need to track satellites. Just after sunset or before sunrise, satellites in LEO are easy to track. They look like slow-moving stars, and they generally move in a west to east direction. With a little practice, you should be able to find one or two satellites a minute. A pair of binoculars will help you get a closer look. Satellites in GEO are difficult to see because they do not appear to move. You and a parent can find out more about how to track specific satellites and space stations on the Internet.

ACTIVITY

Copyright © by Holt, Rinehart and Winston. All rights reserved.

CONNECTION TO Environmental Science

WRITING SKILL **Space Junk** After more than 40 years of space launches, Earth orbits are getting cluttered with "space junk." The United States Space Command—a new branch of the military—tracks more than 10,000 pieces of debris. Left uncontrolled, this debris may become a problem for space vehicles in the future. Write a creative illustrated proposal to clean up space junk.

Remote Sensing and Environmental Change

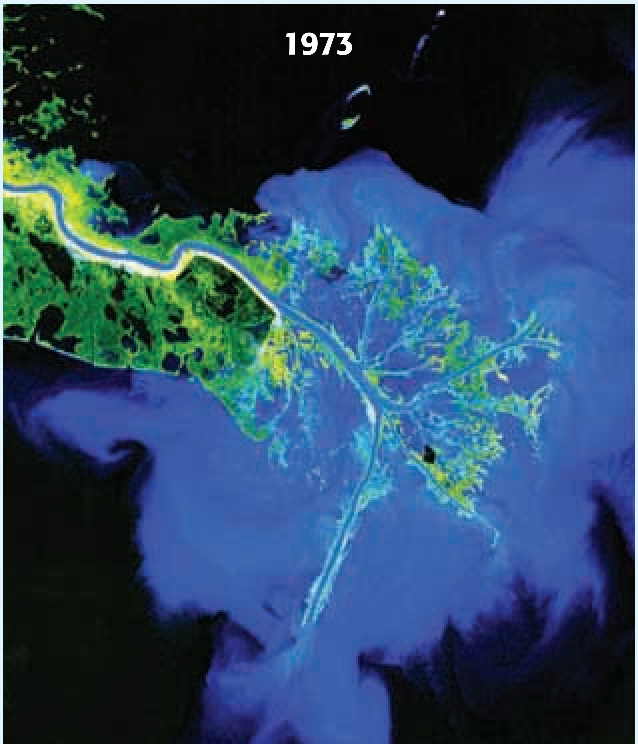
Using satellites, scientists have been able to study the Earth in ways that were never before possible. Satellites gather information by *remote sensing*. Remote sensing is the gathering of images and data from a distance. Remote-sensing satellites measure light and other forms of energy that are reflected from Earth. Some satellites use radar, which bounces high-frequency radio waves off the Earth and measures the returned signal.

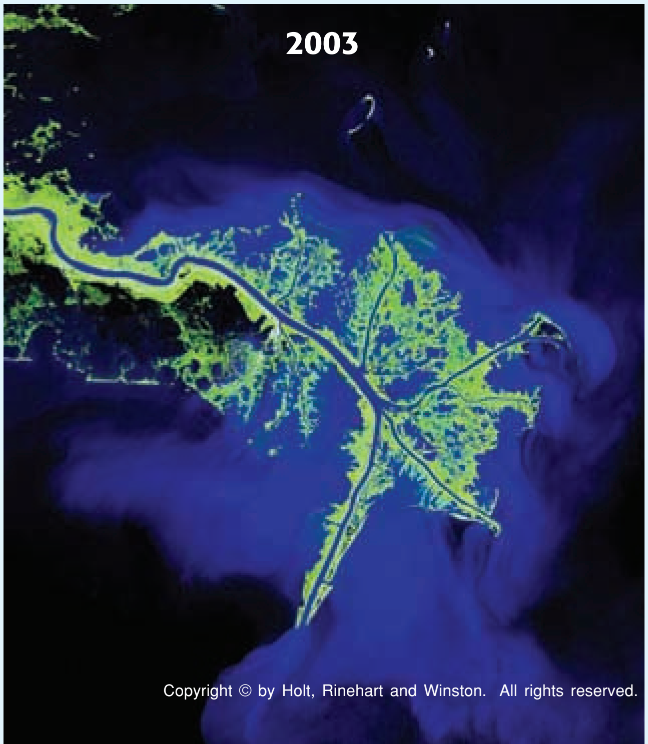
Landsat: Monitoring the Earth from Orbit

One of the most successful remote-sensing projects is the Landsat program, which began in 1972 and continues today. It has given us the longest continuous record of Earth's surface as seen from space. Landsat satellites gather images in several wavelengths—from visible light to infrared. **Figure 5** shows Landsat images of part of the Mississippi Delta. One image was taken in 1973, and the other was taken in 2003. The two images reveal a pattern of environmental change over a 30-year period. The main change is a dramatic reduction in the amount of silt that is reaching the delta. A comparison of the images also reveals a large-scale loss of wetlands in the bottom left of the delta in 2003. The loss of wetlands affects plants and animals living on the delta and the fishing industry.

Figure 5 **The Loss of Wetlands in the Mississippi Delta**

Silt reaching the Mississippi Delta is shown in blue. In 1973 (left), the amount of silt reaching the delta was much greater than in 2003 (right). This reduction led to the rapid loss of wetlands, which are green in this image. Notice the lower left corner of the delta in both images. Areas of wetland loss are black.





Copyright © by Holt, Rinehart and Winston. All rights reserved.

A New Generation of Remote-Sensing Satellites

The Landsat program has produced millions of images that are used to identify and track environmental change on Earth. Satellite remote sensing allows scientists to perform large-scale mapping, look at changes in patterns of vegetation growth, map the spread of urban development, and study the effect of humans on the global environment. In 1999, NASA launched *Terra 1,* the first satellite in NASA's Earth Observing System (EOS) program. Satellites in the EOS program are designed to work together so that they can gather integrated data on environmental change on the land, in the atmosphere, in the oceans, and on the icecaps.

Reading Check **What is unique about the EOS program?**

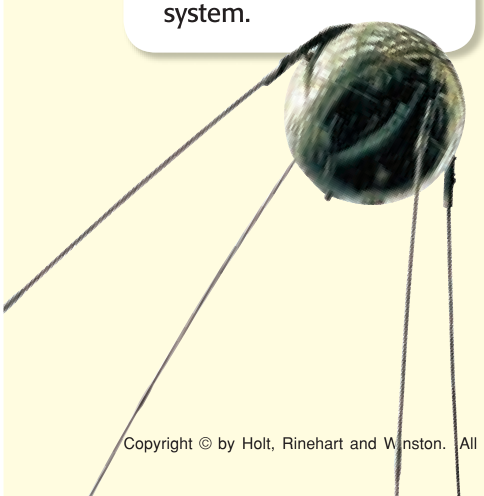
INTERNET ACTIVITY

For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HZ5EXPW.**

SECTION Review

Summary

- *Sputnik 1* was the first artificial satellite. *Explorer 1* was the first U.S. satellite.
- Low Earth orbits are used for making detailed images of the Earth.
- Geostationary orbits are used for communications, navigation, and weather satellites.
- Satellites with remote sensing technology have helped us understand the Earth as a global system.



Using Key Terms

1. Use each of the following terms in a separate sentence: *artificial satellite, low Earth orbit,* and *geostationary orbit.*

Understanding Key Ideas

2. In a low Earth orbit, the speed of a satellite is
   a. slower than the rotational speed of the Earth.
   b. equal to the rotational speed of the Earth.
   c. faster than the rotational speed of the Earth.
   d. None of the above
3. What was the name of the first satellite placed in orbit?
4. List three ways that satellites benefit human society.
5. What was the *Explorer 1*?
6. Explain the differences between LEO and GEO satellites.
7. How does the Global Positioning System work?
8. How do communications satellites relay signals around the curved surface of Earth?

Math Skills

9. The speed required to reach Earth orbit is 8 km/s. What does this equal in *meters per hour*?

Critical Thinking

10. **Applying Concepts** The *Hubble Space Telescope* is located in LEO. Does the telescope move faster or slower around the Earth compared with a geostationary weather satellite? Explain.
11. **Applying Concepts** To triangulate your location on a map, you need to know your distance from three points. If you knew your distance from two points, how many possible places could you occupy?

SCILINKS® NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Artificial Satellites

SciLinks code: HSM0101

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 3

Space Probes

What does the surface of Mars look like? Does life exist anywhere else in the solar system?

READING WARM-UP

Objectives

- Describe five discoveries made by space probes.
- Explain how space-probe missions help us better understand the Earth.
- Describe how NASA's new strategy of "faster, cheaper, and better" relates to space probes.

Terms to Learn

space probe

READING STRATEGY

Reading Organizer As you read this section, make a concept map showing the space probes, the planetary bodies they visited, and their discoveries.

To answer questions like these, scientists send space probes to explore the solar system. A **space probe** is an uncrewed vehicle that carries scientific instruments to planets or other bodies in space. Unlike satellites, which stay in Earth orbit, space probes travel away from the Earth. Space probes are valuable because they can complete missions that would be very dangerous and expensive for humans to undertake.

space probe an uncrewed vehicle that carries scientific instruments into space to collect scientific data

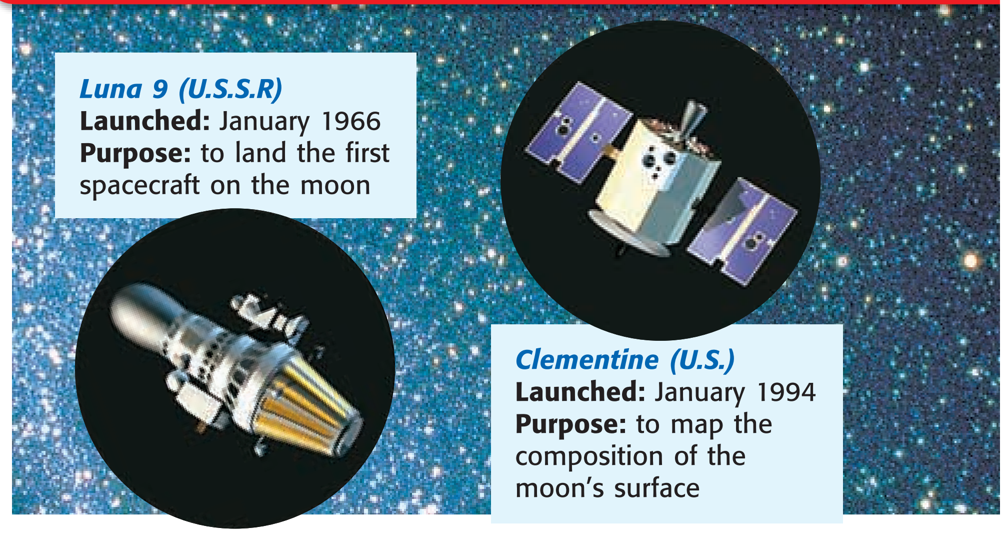
Visits to the Inner Solar System

Because Earth's moon and the inner planets are much closer than the other planets and moons in the solar system, they were the first to be explored by space probes. Let's take a closer look at some missions to the moon, Venus, and Mars.

Luna and Clementine: Missions to the Moon

Luna 1, the first space probe, was launched by the Soviets in 1959 to fly past the moon. In 1966, *Luna 9* made the first soft landing on the moon's surface. During the next 10 years, the United States and the Soviet Union completed more than 30 lunar missions. Thousands of images of the moon's surface were taken. In 1994, the United States probe *Clementine* discovered that craters of the moon may contain water left by comet impacts. In 1998, the *Lunar Prospector* confirmed that frozen water exists on the moon. This ice would be very valuable to a human colony on the moon.

Missions to the Moon



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Venera 9: The First Probe to Land on Venus

The Soviet probe *Venera 9* was the first probe to land on Venus. The probe parachuted into Venus's atmosphere and transmitted images of the surface to Earth. *Venera 9* found that the surface temperature and atmospheric pressure on Venus are much higher than on Earth. The surface temperature of Venus is an average of 464°C—hot enough to melt lead! *Venera 9* also found that the chemistry of the surface rocks on Venus is similar to that of Earth rocks. Perhaps most important, *Venera 9* and earlier missions revealed that Venus has a severe greenhouse effect. Scientists study Venus's atmosphere to learn about the effects of increased greenhouse gases in Earth's atmosphere.

The Magellan Mission: Mapping Venus

In 1989, the United States launched the *Magellan* probe, which used radar to map 98% of the surface of Venus. The radar data were transmitted back to Earth where computers used the data to generate three-dimensional images like the one shown in **Figure 1.** The Magellan mission showed that, in many ways, the geology of Venus is similar to that of Earth. Venus has features that suggest plate tectonics occurs there, as it does on Earth. Venus also has volcanoes, and some of them may be active.

Reading Check **What discoveries were made by *Magellan*?** (*See the Appendix for answers to Reading Checks.*)

Missions to Venus

***Venera 9* (U.S.S.R.)**
Launched: June 1975
Purpose: to record the surface conditions of Venus

***Magellan* (U.S.)**
Launched: May 1989
Purpose: to make a global map of the surface of Venus

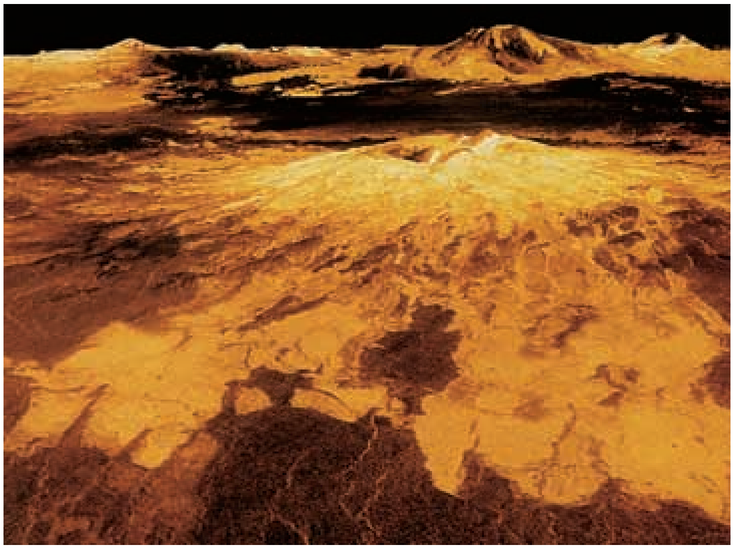
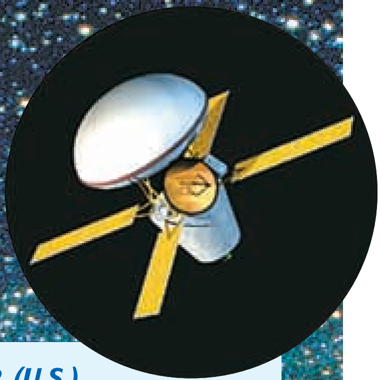


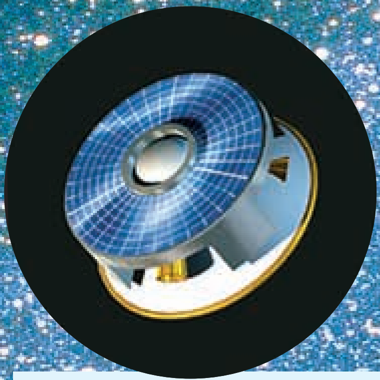
Figure 1 *This false-color image of volcanoes on the surface of Venus was made with radar data transmitted to Earth by* Magellan.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Missions to Mars



Viking 2 ***(U.S.)***
Launched: September 1975
Purpose: to search for life on the surface of Mars



Mars Pathfinder (U.S.)
Launched: December 1996
Purpose: to use inexpensive technology to study the surface of Mars

The Viking Missions: Exploring Mars

In 1975, the United States sent a pair of probes—*Viking 1* and *Viking 2*—to Mars. The surface of Mars is more like the Earth's surface than that of any other planet. For this reason, one of the main goals of the Viking missions was to look for signs of life. The probes contained instruments designed to gather soil and test it for evidence of life. However, no hard evidence was found. The Viking missions did find evidence that Mars was once much warmer and wetter than it is now. This discovery led scientists to ask even more questions about Mars. Did the Martian climate once support life? Why and when did the Martian climate change?

The Mars Pathfinder Mission: Revisiting Mars

More than 20 years later, in 1997, the surface of Mars was visited again by a NASA space probe. The goal of the Mars Pathfinder mission was to show that Martian exploration is possible at a much lower cost than the Viking missions. The probe sent back detailed images of dry water channels on the planet's surface. These images, such as the one shown in **Figure 2,** suggest that massive floods flowed across the surface of Mars relatively recently in the planet's past. The *Mars Pathfinder* successfully landed on Mars and deployed the *Sojourner* rover. *Sojourner* traveled across the surface of Mars for almost three months, collecting data and recording images. The European Space Agency and NASA have many more Mars missions planned for the near future. These missions will pave the way for a crewed mission to Mars that may occur in your lifetime!

Reading Check **What discoveries were made by the Mars Pathfinder mission?**

Figure 2 *The* Mars Pathfinder *took detailed photographs of the Martian surface. Photographs, such as this one, revealed evidence of massive flooding.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Visits to the Outer Solar System

The planets in the outer solar system—Jupiter, Saturn, Uranus, Neptune, and Pluto—are very far away. Probes such as those described below can take 10 years or more to complete their missions.

Pioneer and Voyager: To Jupiter and Beyond

The *Pioneer 10* and *Pioneer 11* space probes were the first to visit the outer planets. Among other things, these probes sampled the *solar wind*—the flow of particles coming from the sun. The Pioneer probes also found that the dark belts on Jupiter provide deep views into Jupiter's atmosphere. In 1983, *Pioneer 10* became the first probe to travel past the orbit of Pluto, the outermost planet.

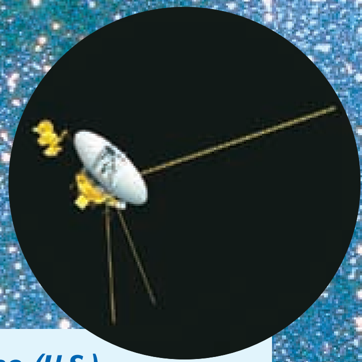
The Voyager space probes were the first to detect Jupiter's faint rings, and *Voyager 2* was the first probe to fly by the four gas giants—Jupiter, Saturn, Uranus, and Neptune. The paths of the Pioneer and Voyager space probes are shown in **Figure 3.** Today, they are near the solar system's edge and some are still sending back data.

The Galileo Mission: A Return to Jupiter

The *Galileo* probe arrived at Jupiter in 1995. While *Galileo* itself began a long tour of Jupiter's moons, it sent a smaller probe into Jupiter's atmosphere to measure its composition, density, temperature, and cloud structure. *Galileo* gathered data about the geology of Jupiter's major moons and Jupiter's magnetic properties. The moons of Jupiter proved to be far more exciting than the earlier Pioneer and Voyager images had suggested. *Galileo* discovered that two of Jupiter's moons have magnetic fields and that one of its moons, Europa, may have an ocean of liquid water under its icy surface.

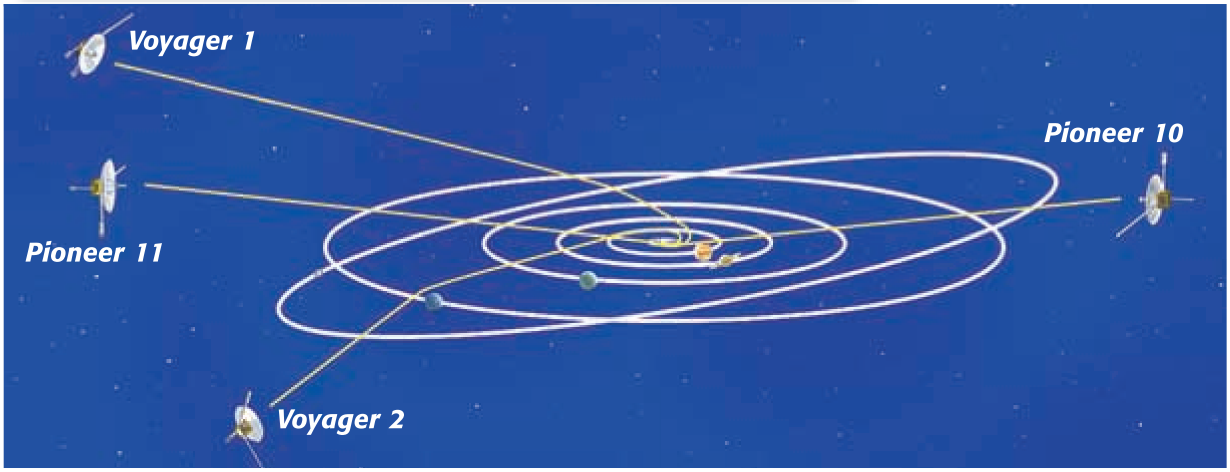
Missions to the Outer Solar System

***Pioneer 10* (U.S.)**
Launched: March 1972
Purpose: to study Jupiter and the outer solar system



***Galileo* (U.S.)**
Launched: October 1989
Purpose: to study Jupiter and its moons

Figure 3 The Orbits of the *Pioneer* and *Voyager* Probes



Copyright © by Holt, Rinehart and Winston. All rights reserved.

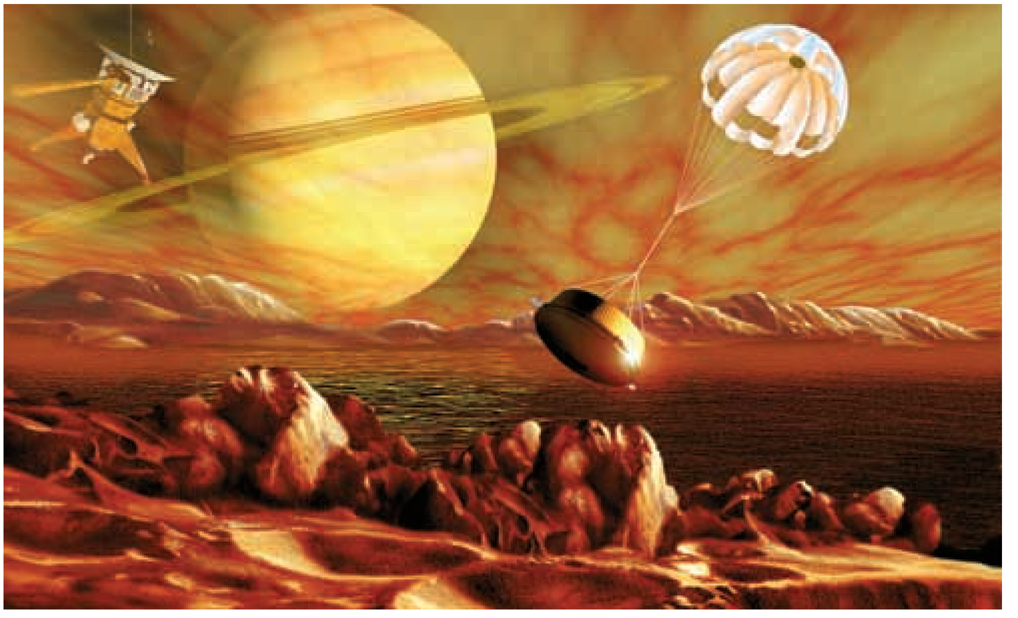


Figure 4 *This artist's view shows the* Huygens *probe parachuting to the surface of Saturn's moon Titan. Saturn and* Cassini *are in the background.*

The Cassini Mission: Exploring Saturn's Moons

In 1997, the *Cassini* space probe was launched on a seven-year journey to Saturn where it will make a grand tour of Saturn's moons. As shown in **Figure 4,** a smaller probe, called the *Huygens* probe, will detach itself from *Cassini* and descend into the atmosphere of Saturn's moon Titan. Scientists are interested in Titan's atmosphere because it may be similar to the Earth's early atmosphere. Titan's atmosphere may reveal clues about how life developed on Earth.

CONNECTION TO Social Studies

Cosmic Message in a Bottle
When the Voyager space probes were launched in 1977, they carried a variety of messages intended for alien civilizations that might find them. In addition to greetings spoken in 55 different languages, a variety of songs, nature sounds, a diagram of the solar system, and photographs of life on Earth were included. Find out more about the message carried by the Voyager missions, and then create your own cosmic message in a bottle.

ACTIVITY

Faster, Cheaper, and Better

The early space probe missions were very large and costly. Probes such as *Voyager 2* and *Galileo* took years to develop. Now, NASA has a vision for missions that are "faster, cheaper, and better." One new program, called Discovery, seeks proposals for smaller science programs. The first six approved Discovery missions include sending small space probes to asteroids, landing on Mars again, studying the moon, and returning comet dust to Earth.

Stardust: Comet Detective

Launched in 1999, the *Stardust* space probe is the first probe to focus only on a comet. The probe will arrive at the comet in 2004 and gather samples of the comet's dust tail. It will return the samples to Earth in 2006. For the first time, pure samples from beyond the orbit of the moon will be brought back to Earth. The comet dust should help scientists better understand how the solar system formed.

Reading Check **What is the mission of the *Stardust* probe?**

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Deep Space 1: Testing Ion Propulsion

Another NASA project is the New Millennium program. Its purpose is to test new technologies that can be used in the future. *Deep Space 1,* shown in **Figure 5,** is the first mission of this program. It is a space probe with an ion-propulsion system. Instead of burning chemical fuel, an ion rocket uses charged particles that exit the vehicle at high speed. An ion rocket follows Newton's third law of motion, but it does so using a unique source of propulsion. Ion propulsion is like sitting on the back of a truck and shooting peas out of a straw. If there were no friction, the truck would gradually accelerate to tremendous speeds.

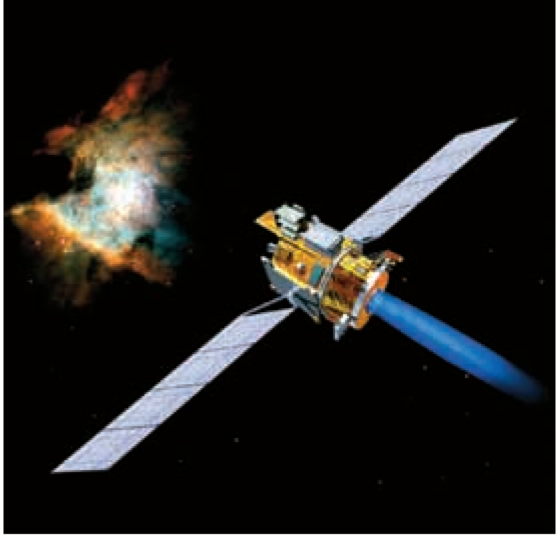


Figure 5 Deep Space 1 *uses a revolutionary type of propulsion—an ion rocket.*

SECTION Review

Summary

- Exploration with space probes began with missions to the moon. Space probes then explored other bodies in the inner solar system.
- Space-probe missions to Mars have focused on the search for signs of water and life.
- The Pioneer and Voyager programs explored the outer solar system.
- Space probe missions have helped us understand Earth's formation and environment.
- NASA's new strategy of "faster, cheaper, and better" seeks to create space-probe missions that are smaller than those of the past.

Using Key Terms

The statements below are false. For each statement, replace the underlined term to make a true statement.

1. Luna 1 discovered evidence of water on the moon.
2. Venera 9 helped map 98% of Venus's surface.
3. Stardust uses ion propulsion to accelerate.

Understanding Key Ideas

4. What is the significance of the discovery of evidence of water on the moon?
   - **a.** Water is responsible for the formation of craters.
   - **b.** Water was left by early space probes.
   - **c.** Water could be used by future moon colonies.
   - **d.** The existence of water proves that there is life on the moon.
5. Describe three discoveries that have been made by space probes.
6. How do missions to Venus, Mars, and Titan help us understand Earth's environment?

Math Skills

7. Traveling at the speed of light, signals from *Voyager 1* take about 12 h to reach Earth. The speed of light is about 299,793 km/s, how far away is the probe?

Critical Thinking

8. **Making Inferences** Why did we need space probes to discover water channels on Mars and evidence of ice on Europa?
9. **Expressing Opinions** What are the advantages of the new Discovery program over the older space-probe missions, and what are the disadvantages?
10. **Applying Concepts** How does *Deep Space 1* use Newton's third law of motion to accelerate?

SCILINKS

NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Space Probes

SciLinks code: HSM1342

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 4

People in Space

One April morning in 1961, a rocket stood on a launch pad in a remote part of the Soviet Union. Inside, a 27-year-old cosmonaut named Yuri Gagarin sat and waited. He was about to do what no human had done before—travel to outer space. No one knew if the human brain would function in space or if he would be instantly killed by radiation.

READING WARM-UP

Objectives

- Summarize the history and future of human spaceflight.
- Explain the benefits of crewed space programs.
- Identify five "space-age spinoffs" that are used in everyday life.

Terms to Learn

space shuttle
space station

READING STRATEGY

Reading Organizer As you read this section, make a flowchart that shows the events of the space race.

On April 12, 1961, Yuri Gagarin, shown in **Figure 1,** became the first human to orbit Earth. The flight lasted 108 minutes. An old woman, her granddaughter, and a cow were the first to see Gagarin as he safely parachuted back to Earth, but the news of his success was quickly broadcast around the world.

The Race Is On

The Soviets were first once again, and the Americans were concerned that their rivals were winning the space race. Therefore, on May 25, 1961, President Kennedy announced, "I believe that the nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to the Earth. No single project in this period will be more impressive to mankind, or more important for the long range exploration of space."

Kennedy's speech took everyone by surprise—even NASA's leaders. Go to the moon? We had not even reached orbit yet! In response to Kennedy's challenge, a new spaceport called Kennedy Space Center was built in Florida and Mission Control was established in Houston, Texas. In February 1962, John Glenn became the first American to orbit the Earth.

Figure 1 *In 1961, Yuri Gagarin (left) became the first person in space. In 1962, John Glenn (right) became the first American to orbit the Earth.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

"The Eagle Has Landed"

Seven years later, on July 20, 1969, Kennedy's challenge was met. The world watched on television as the *Apollo 11* landing module—the *Eagle,* shown in **Figure 2**—landed on the moon. Neil Armstrong became the first human to set foot on a world other than Earth. This moment forever changed the way we view ourselves and our planet. The Apollo missions also contributed to the advancement of science. *Apollo 11* returned moon rocks to Earth for study. Its crew also put devices on the moon to study moonquakes and the solar wind.

Figure 2 *Neil Armstrong took this photo of Edwin "Buzz" Aldrin as Aldrin was about to become the second human to set foot on the moon.*

The Space Shuttle

The Saturn V rockets, which carried the Apollo astronauts to the moon, were huge and very expensive. They were longer than a football field, and each could be used only once. To save money, NASA began to develop the space shuttle program in 1972. A **space shuttle** is a reusable space vehicle that takes off like a rocket and lands like an airplane.

space shuttle a reusable space vehicle that takes off like a rocket and lands like an airplane

The Space Shuttle Gets off the Ground

Columbia, the first space shuttle, was launched on April 12, 1981. Since then, NASA has completed more than 100 successful shuttle missions. If you look at the shuttle *Endeavour* in **Figure 3,** you can see its main parts. The orbiter is about the size of an airplane. It carries the astronauts and payload into space. The liquid-fuel tank is the large red column. Two white solid-fuel booster rockets help the shuttle reach orbit. Then they fall back to Earth along with the fuel tank. The booster rockets are reused, the fuel tank is not. After completing a mission, the orbiter returns to Earth and lands like an airplane.

Figure 3 *The space shuttles are the first reusable space vehicles.*

Reading Check **What are the main parts of the shuttle?** (*See the Appendix for answers to Reading Checks.*)

Shuttle Tragedies

On January 28, 1986, the booster rocket on the space shuttle *Challenger* exploded just after takeoff, killing all seven of its astronauts. On board was Christa McAuliffe, who would have been the first teacher in space. Investigations found that cold weather on the morning of the launch had caused rubber gaskets in the solid fuel booster rockets to stiffen and fail. The failure of the gaskets led to the explosion. The shuttle program resumed in 1988. In 2003, however, the space shuttle *Columbia* exploded as it reentered the atmosphere. All seven astronauts on board were killed. These disasters emphasize the dangers of space exploration that continue to challenge scientists and engineers.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 4 *As this illustration shows, space planes may provide transportation to outer space and around the world.*

Space Planes: The Shuttles of the Future?

NASA is working to develop advanced space systems, such as a space plane. This craft will fly like a normal airplane, but it will have rocket engines for use in space. Once in operation, space planes, such as the one shown in **Figure 4,** may lower the cost of getting material to LEO by 90%. Private companies are also becoming interested in developing space vehicles for commercial use and to make space travel cheaper, easier, and safer.

Space Stations—People Working in Space

space station a long-term orbiting platform from which other vehicles can be launched or scientific research can be carried out

A long-term orbiting platform in space is called a **space station.** On April 19, 1971, the Soviets became the first to successfully place a space station in orbit. A crew of three Soviet cosmonauts conducted a 23-day mission aboard the station, which was called *Salyut 1*. By 1982, the Soviets had put up seven space stations. Because of this experience, the Soviet Union became a leader in space-station development and in the study of the effects of weightlessness on humans. Their discoveries will be important for future flights to other planets—journeys that will take years to complete.

CONNECTION TO Biology

Effects of Weightlessness When a human body stays in space for long periods of time without having to work against gravity, the bones lose mass and muscles become weaker. Find out about the exercises to reduce the loss of bone mass used by astronauts aboard the *International Space Station*. Create an "Astronaut Exercise Book" to share with your friends.

ACTIVITY

Skylab and *Mir*

Skylab, the United States' first space station, was a science and engineering lab used to conduct a wide variety of scientific studies. These studies included experiments in biology and space manufacturing and astronomical observations. Three different crews spent a total of 171 days on *Skylab* before it was abandoned. In 1986, the Soviets began to launch the pieces for a much more ambitious space station called *Mir* (meaning "peace"). Astronauts on *Mir* conducted a wide range of experiments, made many astronomical observations, and studied manufacturing in space. After 15 years, *Mir* was abandoned and it burned up in the Earth's atmosphere in 2001.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

The *International Space Station*

The *International Space Station* (*ISS*), the newest space station, is being constructed in LEO. Russia, the United States, and 14 other countries are designing and building different parts of the station. **Figure 5** shows what the *ISS* will look like when it is completed. The *ISS* is being built with materials brought up on the space shuttles and by Russian rockets. The United States is providing lab modules, the supporting frame, solar panels, living quarters, and a biomedical laboratory. The Russians are contributing a service module, docking modules, life-support and research modules, and transportation to and from the station. Other components will come from Japan, Canada, and several European countries.

Reading Check **What contributions are the Americans and Russians making to the *ISS*?**

Research on the *International Space Station*

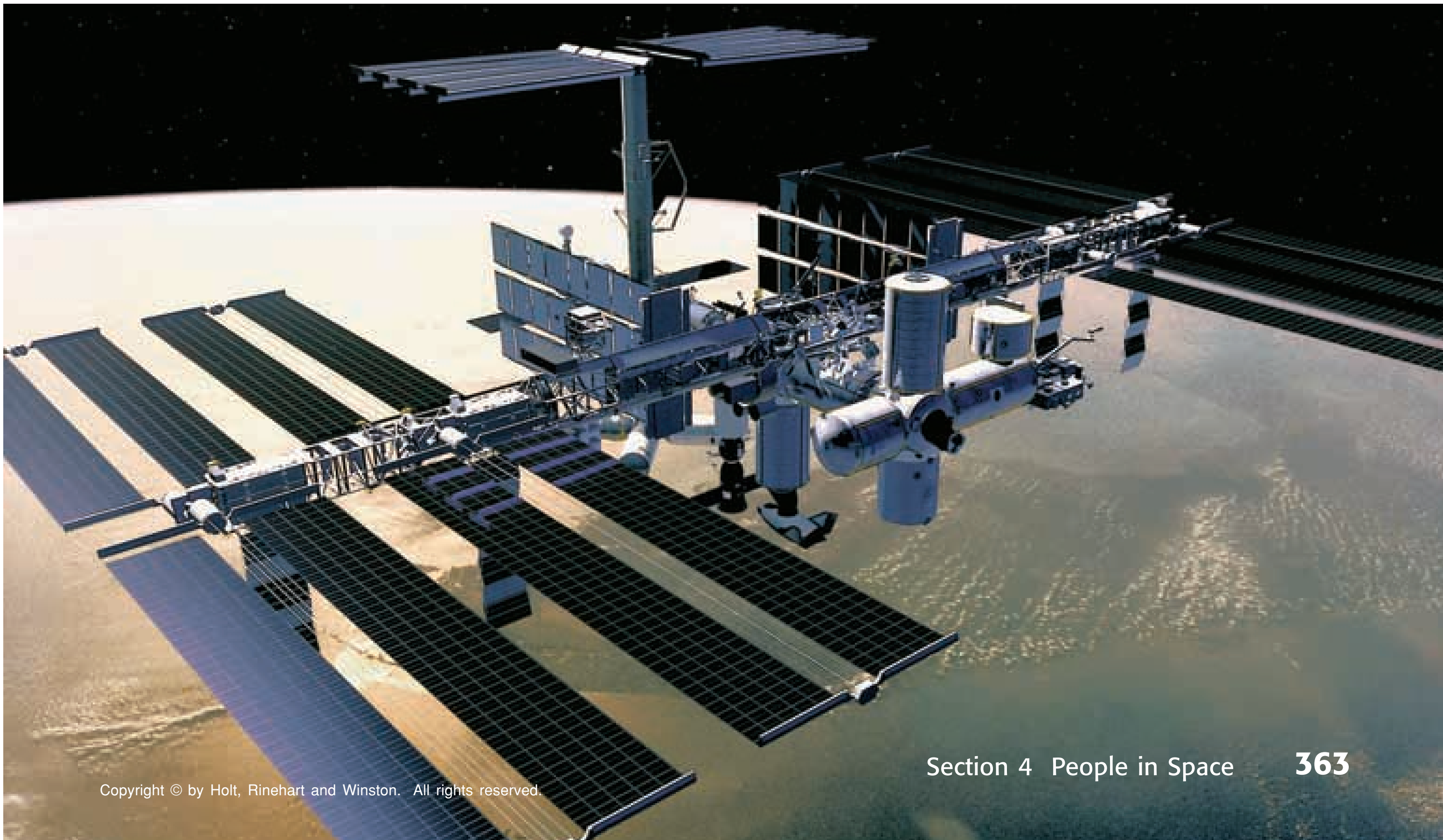
The *ISS* will provide many benefits—some of which we cannot predict. What scientists do know is that it will be a unique, space-based facility to perform space-science experiments and to test new technologies. Much of the space race involved political and military rivalry between the Soviet Union and the United States. Hopefully, the *ISS* will promote cooperation between countries while continuing the pioneering spirit of the first astronauts and cosmonauts.

CONNECTION TO Social Studies

Oral Histories The exciting times of the Apollo moon missions thrilled the nation. Interview adults in your community about their memories of those times. Prepare a list of questions first, and have your questions and contacts approved by your teacher. If possible, use a tape recorder or video camera to record the interviews. As a class, create a library of your oral histories for future students.

ACTIVITY

Figure 5 *When the* International Space Station *is completed, it will be about the size of a soccer field and will weigh about 500 tons.*



Copyright © by Holt, Rinehart and Winston. All rights reserved.

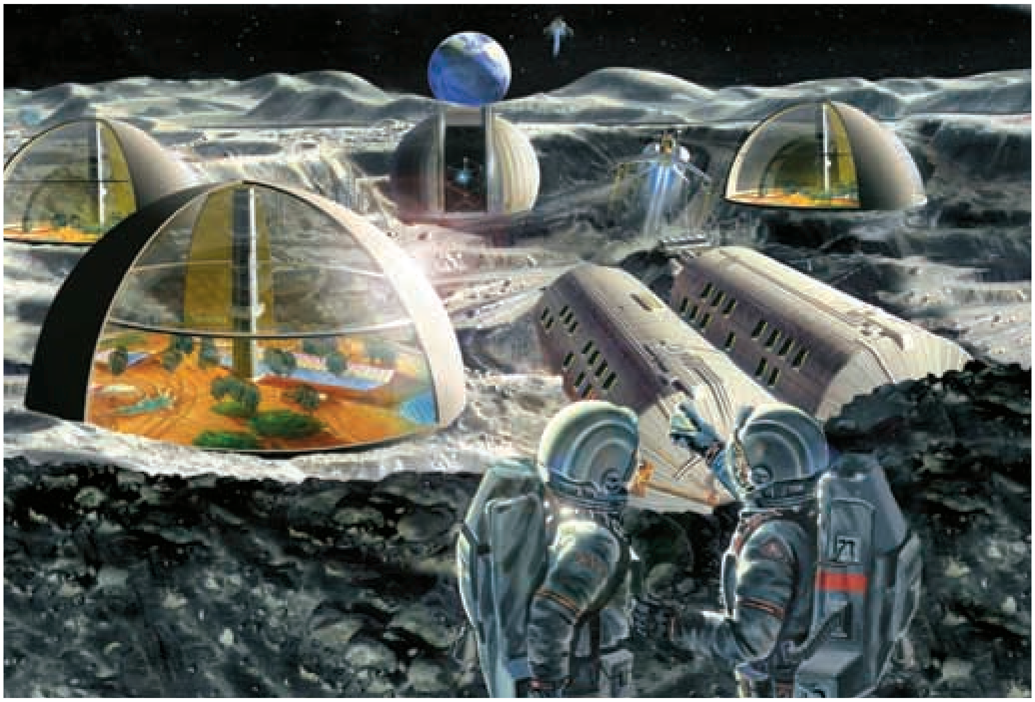


Figure 6 *As this illustration shows, humans may eventually establish a colony on the moon or on Mars.*

To the Moon, Mars, and Beyond

We may eventually need resources beyond what Earth can offer. Space offers many such resources. The moon will be an important part of the further study and exploration of the solar system. For example, the far side of the moon can be 100 times as dark as any observatory site on Earth. A base on the moon similar to the one shown in **Figure 6** could be used to manufacture materials in low gravity or in a vacuum. A colony on the moon or on Mars could be an important link to bringing space resources to Earth. The key will be to make space missions economically worthwhile.

Figure 7 *Aerogel is the lightest solid on Earth. Aerogel is only 3 times as heavy as air and has 39 times the insulating properties of the best fiberglass insulation.*

The Benefits of the Space Program

The exploration of space is a challenge to human courage and a quest for new knowledge of ourselves and the universe. We have visited the moon and spent decades exploring space. So, why should we continue to explore space? When exploring space, scientists not only learn more about space itself but also gain a large amount of knowledge from developing the missions to space. The information gained by developing these missions can be used to make our everyday lives better. For example, space missions required the development of new pumps. Later, this pump technology enabled scientists to develop artificial hearts. Computerized processes that were originally developed to manage launch preparations for the space shuttle are now used in businesses all over the world. NASA's aerogel, shown in **Figure 7,** may become an energy-saving replacement for windows in the future. The cost of space exploration is high, but the rewards are great.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Space-Age Spinoffs

Technologies that were developed for the space programs but are now used in everyday life are called *space-age spinoffs*. There are dozens of examples of common items that were first developed for the space programs. Cordless power tools, such as the drill shown in **Figure 8,** were first developed for use on the moon by the Apollo astronauts. Hand-held cameras that were developed to study the heat emitted from the space shuttle are now used by firefighters to detect dangerous hot spots in fires. In addition to developing new, everyday technologies, the space program has created new tools for scientists to conduct future research.

Figure 8 *Cordless power tools were originally developed for astronauts to drill samples from the moon.*

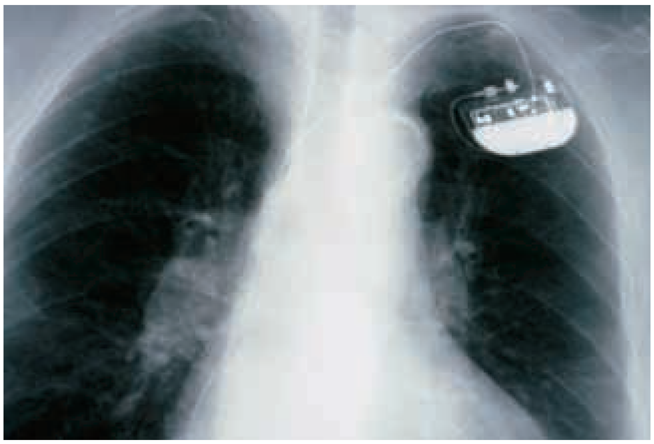
Reading Check **What are space-age spinoffs?**

Spinoffs in Health and Medicine

Many people who have heart problems may rely on a pacemaker, which uses wireless technology developed by NASA. A pacemaker, shown in **Figure 9,** is a small machine that is inserted into a patient's body. The machine helps regulate the patient's heart rate.

You may be more familiar with another tool developed from space technology. The ear thermometer in **Figure 9** is used to measure a person's body temperature. The thermometer uses a special lens that detects infrared energy, which we feel as heat. The lens detects the infrared energy of the body. The lens used in this type of thermometer was originally developed to detect the birth of stars in space!

Figure 9 **Space-Age Spinoffs in Medicine**



Doctors can program a patient's pacemaker wirelessly. This wireless technology was originally developed for the space program.

The technology that was developed to detect the birth of new stars in space is now used in ear thermometers to measure body temperature.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 10 **Materials from Space-Age Spinoffs**

Chemicals invented by NASA were used to make this heat-resistant suit, allowing this engineer to escape from the fire unharmed.

NASA's aircraft cushion material is now being used for shock-absorbing sports helmets.

Space-Age Materials

Several types of materials that we use every day were originally designed for use in space. Examples include fire-resistant and heat-resistant materials. The heat-resistant suit shown in **Figure 10** was made from chemically treated fabric. The chemicals were originally developed to treat fabrics for use in spacesuits and inside spacecraft.

What kind of common object would you expect to be made from material used for aircraft cushions? Protective helmets, of course! Material developed by NASA for aircraft passenger seats is now used in shock-absorbing helmets and shin guards, as shown in **Figure 10.** Space technology is also responsible for the scratch-resistant lenses that are used in eyeglasses.

CONNECTION TO Language Arts

Types of Technology Space-age spinoffs are evidence that technology can take on many forms. Spinoffs can be anything from tools or hardware to computer programs or special processes. Make a list of the types of technology that you use every day. Then, write a paragraph describing what your life would be like without these technologies.

Transportation and Safety Spinoffs

Spinoff technology has led to transportation and safety advancements, such as safer bridges, improved automobile designs, and storm-warning devices. Smoke detectors were originally used on the orbiting space station *Skylab* to detect toxic vapors. Material developed for the *Viking Lander* parachute shroud is 5 times as strong as steel and has been used to make tires. These new tires are very tough and work well in bad weather. Three types of NASA-developed technology are used to design and test school buses. With this new technology, manufacturers are able to test new school bus designs for safety before even making the school bus!

Reading Check **What is an example of a transportation spinoff?**

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION Review

Summary

- In 1961, the Soviet cosmonaut Yuri Gagarin became the first person in space. In 1969, Neil Armstrong became the first person on the moon.
- During the 1970s, the United States focused on developing the space shuttle. The Soviets focused on developing space stations.
- The United States, Russia, and 14 other countries are currently developing the *International Space Station.*
- There have been many scientific, economic, and social benefits of the space programs. Space-age spinoffs are some examples of these benefits.

Using Key Terms

1. Use each of the following terms in a separate sentence: *space shuttle* and *space station.*

Using Key Ideas

2. What is the main difference between the space shuttles and other space vehicles?
   a. The space shuttles are powered by liquid rocket fuel.
   b. The space shuttles take off like a plane and land like a rocket.
   c. The space shuttles are reusable.
   d. The space shuttles are not reusable.

3. Describe the history and future of human spaceflight. How was the race to explore space influenced by the Cold War?

4. Describe five space-age spinoffs.

5. How will space stations help in the exploration of space?

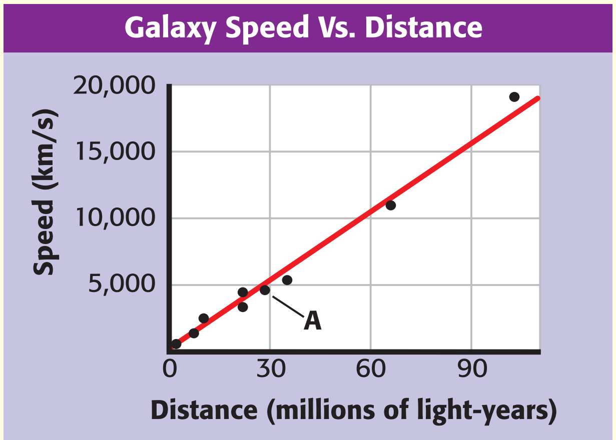
Critical Thinking

6. **Making Inferences** Why did the United States stop sending people to the moon after the Apollo program ended?

7. **Expressing Opinions** Imagine that you are a U.S. senator reviewing NASA's proposed budget. Write a two-paragraph statement expressing your opinion about increasing or decreasing funding for NASA.

Interpreting Graphics

Use the graph below to answer the question that follows.



8. Look at the point that represents galaxy A in the graph. How far is galaxy A from Earth, and how fast is it moving away from Earth?

SCILINKS® NSTA
Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Space Exploration and Space Stations

SciLinks code: HSM1430

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Using Scientific Methods

Inquiry Lab

Water Rockets Save the Day!

Imagine that for the big Fourth of July celebration, you and your friends had planned a full day of swimming, volleyball, and fireworks at the lake. You've just learned, however, that the city passed a law that bans all fireworks within city limits. But you do not give up so easily on having fun. Last year at summer camp, you learned how to build water rockets. And you have kept the launcher in your garage since then. With a little bit of creativity, you and your friends are going to celebrate with a splash!

OBJECTIVES

Predict which design features would improve a rocket's flight.

Design and build a rocket that includes your design features.

Test your rocket design, and evaluate your results.

MATERIALS

- bottle, soda, 2 L
- clay, modeling
- foam board
- rocket launcher
- scissors
- tape, duct
- watch or clock that indicates seconds
- water

SAFETY

Ask a Question

1. What is the most efficient design for a water rocket?

Form a Hypothesis

2. Write a hypothesis that provides a possible answer to the question above.

Test the Hypothesis

3. Decide how your rocket will look, and then draw a sketch.
4. Using only the materials listed, decide how to build your rocket. Write a description of your plan, and have your teacher approve your plan. Keep in mind that you will need to leave the opening of your bottle clear. The bottle opening will be placed over a rubber stopper on the rocket launcher.
5. Fins are often used to stabilize rockets. Do you want fins on your water rocket? Decide on the best shape for the fins, and then decide how many fins your rocket needs. Use the foam board to construct the fins.
6. Your rocket must be heavy enough to fly in a controlled manner. Consider using clay in the body of your rocket to provide some additional weight and stability.
7. Pour water into your rocket until the rocket is one-third to one-half full.
8. Your teacher will provide the launcher and will assist you during blastoff. Attach your rocket to the launcher by placing the opening of the bottle on the rubber stopper.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

9 When the rocket is in place, clear the immediate area and begin pumping air into your rocket. Watch the pump gauge, and take note of how much pressure is needed for liftoff. **Caution:** Be sure to step back from the launch site. You should be several meters away from the bottle when you launch it.

10 Use the watch to time your rocket's flight. How long was your rocket in the air?

11 Make small changes in your rocket design that you think will improve the rocket's performance. Consider using different amounts of water and clay or experimenting with different fins. You may also want to compare your design with those of your classmates.

Analyze the Results

1 **Describing Events** How did your rocket perform? If you used fins, do you think they helped your flight? Explain your answer.

2 **Explaining Results** What do you think propelled your rocket? Use Newton's third law of motion to explain your answer.

3 **Analyzing Results** How did the amount of water in your rocket affect the launch?

Draw Conclusions

4 **Drawing Conclusions** What modifications made your rocket fly for the longest time? How did the design help the rockets fly so far?

5 **Evaluating Results** Which group's rocket was the most stable? How did the design help the rocket fly straight?

6 **Making Predictions** How can you improve your design to make your rocket perform even better?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Chapter Review

USING KEY TERMS

For each pair of terms, explain how the meanings of the terms differ.

1. *geostationary orbit* and *low Earth orbit*
2. *space probe* and *space station*
3. *artificial satellite* and *moon*

Complete each of the following sentences by choosing the correct term from the word bank.

escape velocity	oxygen
nitrogen	thrust

4. The force that accelerates a rocket is called ___.
5. Rockets need to have ___ in order to burn fuel.

UNDERSTANDING KEY IDEAS

Multiple Choice

6. Whose rocket research team surrendered to the Americans at the end of World War II?
   - **a.** Konstantin Tsiolkovsky's
   - **b.** Robert Goddard's
   - **c.** Wernher von Braun's
   - **d.** Yuri Gargarin's
7. Rockets work according to Newton's
   - **a.** first law of motion.
   - **b.** second law of motion.
   - **c.** third law of motion.
   - **d.** law of universal gravitation.
8. The first artificial satellite to orbit the Earth was
   - **a.** *Pioneer 4.*
   - **b.** *Explorer 1.*
   - **c.** *Voyager 2.*
   - **d.** *Sputnik 1.*
9. Communications satellites are able to transfer TV signals between continents because communications satellites
   - **a.** are located in LEO.
   - **b.** relay signals past the horizon.
   - **c.** travel quickly around Earth.
   - **d.** can be used during the day and night.
10. GEO is a better orbit for communications satellites because satellites that are in GEO
    - **a.** remain in position over one spot.
    - **b.** have polar orbits.
    - **c.** do not revolve around the Earth.
    - **d.** orbit a few hundred kilometers above the Earth.
11. Which space probe discovered evidence of water at the moon's south pole?
    - **a.** *Luna 9*
    - **b.** *Viking 1*
    - **c.** *Clementine*
    - **d.** *Magellan*
12. When did humans first set foot on the moon?
    - **a.** 1959
    - **b.** 1964
    - **c.** 1969
    - **d.** 1973
13. Which of the following planets has not yet been visited by space probes?
    - **a.** Venus
    - **b.** Neptune
    - **c.** Mars
    - **d.** Pluto

Copyright © by Holt, Rinehart and Winston. All rights reserved.

14 Which of the following space probes has left our solar system?

a. *Galileo*
b. *Magellan*
c. *Viking 10*
d. *Pioneer 10*

15 Based on space-probe data, which of the following is the most likely place in our solar system to find liquid water?

a. the moon
b. Mercury
c. Europa
d. Venus

Short Answer

16 Describe how Newton's third law of motion relates to the movement of rockets.

17 What is one disadvantage that objects in LEO have?

18 Why did the United States develop the space shuttle?

19 How does data from satellites help us understand the Earth's environment?

CRITICAL THINKING

20 **Concept Mapping** Use the following terms to create a concept map: *orbital velocity, thrust, LEO, artificial satellites, escape velocity, space probes, GEO,* and *rockets*.

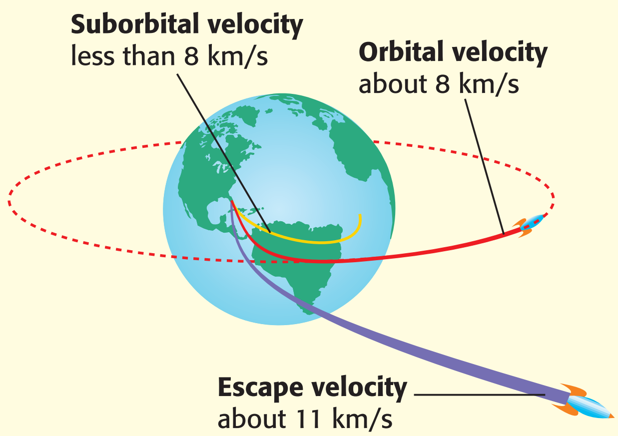
21 **Making Inferences** What is the difference between speed and velocity?

22 **Applying Concepts** Why must rockets that travel in outer space carry oxygen with them?

23 **Expressing Opinions** What impact has space research had on scientific thought, on society, and on the environment?

INTERPRETING GRAPHICS

The diagram below illustrates suborbital velocity, orbital velocity, and escape velocity. Use the diagram below to answer the questions that follow.



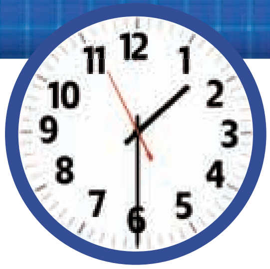
24 Could a rocket traveling at 6 km/s reach orbital velocity?

25 If a rocket traveled for 3 days at the minimum escape velocity, how far would the rocket travel?

26 How much faster would a rocket traveling in orbital velocity need to travel to reach escape velocity?

27 If the escape velocity for a planet was 9 km/s, would you assume that the mass of the planet was more or less than the mass of Earth?

Copyright © by Holt, Rinehart and Winston. All rights reserved.



Standardized Test Preparation

READING

Read each of the passages below. Then, answer the questions that follow each passage.

Passage 1 One of the strange things about living in space is free fall, the reduced effect of gravity. Everything inside the *International Space Station* that is not fastened down will float! The engineers who designed the space station have come up with some intriguing solutions to this problem. For example, each astronaut sleeps in a sack similar to a sleeping bag that is fastened to the module. The sack keeps the astronauts from floating around while they sleep. Astronauts shower with a hand-held nozzle. Afterward, the water droplets are vacuumed up. Other problems that are being studied include how to prepare and serve food, how to design an effective toilet, and how to dispose of waste.

1. What is the main idea of the passage?

A There is no gravity in space.
B Astronauts will stay aboard the space station for long periods of time.
C Living in free fall presents interesting problems.
D Sleeping bags are needed to keep astronauts warm in space.

2. Which of the following is a problem mentioned in the passage?

F how to dissipate the heat of reentry
G how to maintain air pressure
H how to serve food
I how to listen to music

3. Which of the following words is the best antonym for *intriguing*?

A authentic
B boring
C interesting
D unsolvable

Passage 2 In 1999, the crew of the space station *Mir* tried to place a large, umbrella-like mirror in orbit. The mirror was designed to reflect sunlight to Siberia. The experiment failed because the crew was unable to unfold the mirror. If things had gone as planned, the beam of reflected sunlight would have been 5 to 10 times brighter than the light from the moon! If the first space mirror had worked, Russia was planning to place many more mirrors in orbit to lengthen winter days in Siberia, extend the growing season, and even reduce the amount of electricity needed for lighting. Luckily, the experiment failed. If it had succeeded, the environmental effects of extra daylight in Siberia would have been catastrophic. Astronomers were concerned that the mirrors would cause light pollution and obstruct their view of the universe. Outer space should belong to all of humanity, and any project of this kind, including placing advertisements on the moon, should be banned.

1. Which of the following is a statement of opinion?

A Astronomers were concerned about the effects of the space mirror.
B Outer space should belong to all of humanity.
C The experiment failed because the mirror could not unfold.
D Russia was planning to place many more mirrors in orbit.

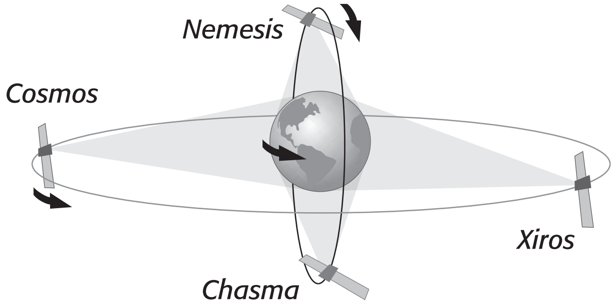
2. What can you infer about the location of Siberia?

F It is near the equator.
G It is closer to the equator than it is to the North Pole.
H It is closer to the North Pole than it is to the equator.
I It is the same distance from the equator as it is from the North Pole.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

INTERPRETING GRAPHICS

The diagram below shows the location of satellites in LEO and GEO. Use the diagram below to answer the questions that follow.



1. Which satellites are always located over the same spot on Earth?
   A *Xiros* and *Chasma*
   B *Xiros* and *Cosmos*
   C *Nemesis* and *Cosmos*
   D *Chasma* and *Nemesis*

2. Which satellites are likely to be spy satellites?
   F *Xiros* and *Cosmos*
   G *Xiros* and *Chasma*
   H *Chasma* and *Nemesis*
   I *Nemesis* and *Cosmos*

3. Which satellites are likely to be communications satellites?
   A *Chasma* and *Nemesis*
   B *Nemesis* and *Cosmos*
   C *Xiros* and *Cosmos*
   D *Xiros* and *Chasma*

4. Which satellites are traveling in an orbit that is 90° with respect to the direction of Earth's rotation?
   F *Nemesis* and *Cosmos*
   G *Xiros* and *Chasma*
   H *Nemesis and Chasma*
   I *Xiros* and *Cosmos*

MATH

Read each question below, and choose the best answer.

1. To escape Earth's gravity, a rocket must travel at least 11 km/s. About how many hours would it take to get to the moon at this speed? (On average, the moon is about 384,500 km away from Earth.)
   A 1 h
   B 7 h
   C 8 h
   D 10 h

2. The Saturn V launch vehicle, which carried the Apollo astronauts into space, had a mass of about 2.7 million kilograms and carried about 2.5 million kilograms of propellant. What percentage of Saturn V's mass was propellant?
   F 9.25%
   G 9%
   H 92.5%
   I 90%

3. Scientists discovered that when a person is in orbit, bone mass in the lower hip and spine is lost at a rate of 1.2% per month. At that rate, how long would it take for 7.2% of bone mass to be lost?
   A 4 months
   B 6 months
   C 7.2 months
   D 8 months

4. The space shuttle can carry 25,400 kg of cargo into orbit. Assume that the average astronaut has a mass of 75 kg and that each satellite has a mass of 4,300 kg. If a shuttle mission is already carrying 9,000 kg of equipment and 10 astronauts, how many satellites can the shuttle carry?
   F 2
   G 3
   H 4
   I 5

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Science in Action

Science, Technology, and Society

Mission to Mars

In spring 2003, two cutting-edge NASA rovers were sent on a mission to Mars. When they reach their destination, they will parachute through the thin Martian atmosphere and land on the surface. First, the rovers will use video and infrared cameras to look around. Then, for at least 92 Earth days (90 Martian days), the rovers will explore the surface of Mars. They will gather geologic evidence of liquid water because liquid water may have enabled Mars to support life in the past. Each rover will carry five scientific tools and a Rock Abrasion Tool, or "RAT," which will grind away rock surfaces to expose the rock interiors for scientific tests. Stay tuned for more news from Mars!

Language Arts ACTIVITY

Watch for stories about this mission in newspapers and magazines. If you read about a discovery on Mars, bring a copy of the article to share with your class. As a class, compile a scrapbook entitled "Mars in the News."

Weird Science

Flashline Mars Arctic Research Station

If you wanted to visit a place on Earth that is like the surface of Mars, where would you go? You might head to an impact crater on Devon Island, close to the Arctic circle. The rugged terrain and harsh weather there resemble what explorers will find on Mars, although Mars has no breathable air and is a lot colder. In the summer, volunteers from the Mars Society live in an experimental base in the crater and test technology that might be used on Mars. The volunteers try to simulate the experience of explorers on Mars. For example, the volunteers wear spacesuits when they go outside, and they explore the landscape by using rovers. They even communicate with the outside world using types of technology likely to be used on Mars. These dedicated volunteers have already made discoveries that will help NASA plan a crewed mission to Mars!

Social Studies ACTIVITY

A Mars mission could require astronauts to endure nearly two years of extreme isolation. Research how NASA would prepare astronauts for the psychological pressures of a mission to Mars.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Franklin Chang-Diaz

Astronaut You have to wear a suit, but the commute is not too long. In fact, it is only about eight and a half minutes, and what a view on your way to work! Astronauts, such as Franklin Chang-Diaz, have one of the most exciting jobs on Earth—or in space. Chang-Diaz has flown on seven space shuttle missions and has completed three space walks. Since the time he became an astronaut in 1981, Chang-Diaz has spent more than 1,601 hours (66 days) in space.

Chang-Diaz was born in San Jose, Costa Rica. He earned a degree in mechanical engineering in 1973 and received a doctorate in applied plasma physics from the Massachusetts Institute of Technology (MIT) in 1977. His work in physics attracted the attention of NASA, and he began training at the Johnson Space Center in Houston, Texas. In addition to doing research on the space shuttle, Chang-Diaz has worked on developing plasma propulsion systems for long space flights. He has also helped create closer ties between astronauts and scientists by starting organizations such as the Astronaut Science Colloquium Program and the Astronaut Science Support Group. If you want to find out more about what it takes to be an astronaut, look on NASA's Web site.

Math ACTIVITY

If 1 out of 120 people interviewed by NASA is selected for astronaut training, how many people will be selected for training if 10,680 people are interviewed?

As this mission patch shows, Chang-Diaz flew on the 111th space shuttle mission.

To learn more about these Science in Action topics, visit go.hrw.com and type in the keyword **HZ5EXPF.**

Current Science

Check out Current Science® articles related to this chapter by visiting go.hrw.com. Just type in the keyword HZ5CS22.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

UNIT 4

TIMELINE

Energy on the Move

Can you imagine living in a world with no electricity, microwaves, or cars? In this unit, you will explore what makes all these things work—energy. You will find out how different forms of energy can be converted into other forms of energy. You will also learn about temperature and heat. This timeline shows some of the inventions and discoveries made throughout history as people have advanced their understanding of energy.

Around 3000 BCE

The sail is used in Egypt. Sails use the wind rather than human power to move boats through the water.

1818

German inventor Baron Karl von Drais de Sauerbrun exhibits the first two-wheeled, rider-propelled machine. Made of wood, this early machine paves the way for the invention of the bicycle.

1948

Maria Telkes, a Hungarian-born physicist, designs the heating system for the first solar-heated house.

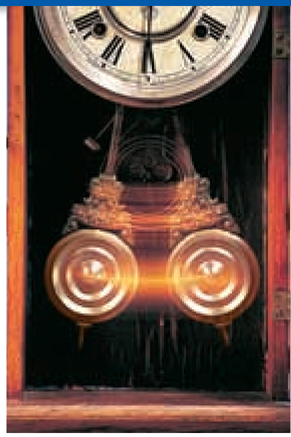
1972

The first American self-service gas station opens.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Around
200 BCE
Under the Han dynasty, the Chinese become one of the first civilizations to use coal as fuel.

1656
Dutch scientist Christiaan Huygens invents the pendulum clock.



1776
The American colonies declare their independence from Great Britain.

1893
The "Clasp Locker," an early zipper, is patented.

1908
The automobile age begins with the mass production of the Ford Model T.

1926
American scientist Robert Goddard launches the first rocket powered by liquid fuel. The rocket reaches a height of 12.5 m and a speed of 97 km/h.

1988
A wind-powered generator begins generating electrical energy in Scotland's Orkney Islands.

2000
The 2000 Olympic Summer Games are held in Sydney, Australia.

2001
A two-wheeled, battery-powered "people mover" is introduced. Gyroscopes and tilt sensors allow riders to guide the scooter-like transporter by leaning.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

13

Energy and Energy Resources

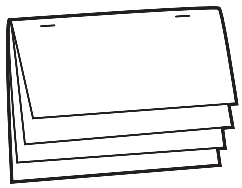
About the PHOTO

Imagine that you're a driver in this race. Your car needs a lot of energy to finish. So, it probably needs a lot of gasoline, right? No, it just needs a lot of sunshine! This car runs on solar energy. Solar energy is one of the many forms of energy. Energy is needed to drive a car, turn on a light bulb, play sports, and walk to school. Energy is always being changed into different forms for different uses.

PRE-READING ACTIVITY

FOLDNOTES

Layered Book Before you read the chapter, create the FoldNote entitled "Layered Book" described in the **Study Skills** section of the Appendix. Label the tabs of the layered book with "Types of energy," "Energy conversions," "Conservation of energy," and "Energy resources." As you read the chapter, write information you learn about each category under the appropriate tab.



Copyright © by Holt, Rinehart and Winston. All rights reserved.

START-UP ACTIVITY

Energy Swings!

In this activity, you'll observe a moving pendulum to learn about energy.

Procedure

1. Make a pendulum by tying a **50 cm long string** around the hook of a **100 g hooked mass.**
2. Hold the string with one hand. Pull the mass slightly to the side, and let go of the mass without pushing it. Watch it swing at least 10 times.
3. Record your observations. Note how fast and how high the pendulum swings.
4. Repeat step 2, but pull the mass farther to the side.
5. Record your observations. Note how fast and how high the pendulum swings.

Analysis

1. Does the pendulum have energy? Explain your answer.
2. What causes the pendulum to move?
3. Do you think the pendulum had energy before you let go of the mass? Explain your answer.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 1

What Is Energy?

It's match point. The crowd is silent. The tennis player tosses the ball into the air and then slams it with her racket. The ball flies toward her opponent, who swings her racket at the ball. THWOOSH!! *The ball goes into the net, causing it to shake. Game, set, and match!!*

The tennis player needs energy to slam the ball with her racket. The ball also must have energy in order to cause the net to shake. Energy is around you all of the time. But what, exactly, is energy?

READING WARM-UP

Objectives

- Explain the relationship between energy and work.
- Compare kinetic and potential energy.
- Describe the different forms of energy.

Terms to Learn

energy
kinetic energy
potential energy
mechanical energy

READING STRATEGY

Discussion Read this section silently. Write down questions that you have about this section. Discuss your questions in a small group.

Energy and Work: Working Together

In science, **energy** is the ability to do work. Work is done when a force causes an object to move in the direction of the force. How do energy and work help you play tennis? The tennis player in **Figure 1** does work on her racket by exerting a force on it. The racket does work on the ball, and the ball does work on the net. When one object does work on another, energy is transferred from the first object to the second object. This energy allows the second object to do work. So, work is a transfer of energy. Like work, energy is expressed in units of joules (J).

Reading Check **What is energy?** (*See the Appendix for answers to Reading Checks.*)

energy the capacity to do work

Figure 1 *The tennis player does work and transfers energy to the racket. With this energy, the racket can then do work on the ball.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Kinetic Energy

In tennis, energy is transferred from the racket to the ball. As it flies over the net, the ball has kinetic (ki NET ik) energy. **Kinetic energy** is the energy of motion. All moving objects have kinetic energy. Like all forms of energy, kinetic energy can be used to do work. For example, kinetic energy allows a hammer to do work on a nail, as shown in **Figure 2.**

kinetic energy the energy of an object that is due to the object's motion

Kinetic Energy Depends on Mass and Speed

An object's kinetic energy can be found by the following equation:

$$\textit{kinetic energy} = \frac{mv^2}{2}$$

The m stands for the object's mass in kilograms. The v stands for the object's speed. The faster something is moving, the more kinetic energy it has. Also, the greater the mass of a moving object, the greater its kinetic energy is.

A large car has more kinetic energy than a car that has less mass and that is moving at the same speed does. But as you can see from the equation, speed is squared. So speed has a greater effect on kinetic energy than mass does. For this reason, car crashes are much more dangerous at higher speeds than at lower speeds. A moving car has *4 times* the kinetic energy of the same car going half the speed! This is because it's going twice the speed of the slower car, and 2 squared is 4.

Figure 2 *When you swing a hammer, you give it kinetic energy, which does work on the nail.*

MATH FOCUS

Kinetic Energy What is the kinetic energy of a car that has a mass of 1,200 kg and is moving at a speed of 20 m/s?

Step 1: Write the equation for kinetic energy.

$$KE = \frac{mv^2}{2}$$

Step 2: Replace m and v with the measurements given, and solve.

$$KE = \frac{1{,}200 \text{ kg} \times (20 \text{ m/s})^2}{2}$$

$$KE = \frac{1{,}200 \text{ kg} \times 400 \text{ m}^2/\text{s}^2}{2}$$

$$KE = \frac{480{,}000 \text{ kg}\bullet\text{m}^2/\text{s}^2}{2}$$

$$KE = 240{,}000 \text{ kg}\bullet\text{m}^2/\text{s}^2 = 240{,}000 \text{ J}$$

Now It's Your Turn

1. What is the kinetic energy of a car that has a mass of 2,400 kg and is moving at 20 m/s? How does this kinetic energy compare to the kinetic energy of the car in the example given at left?
2. What is the kinetic energy of a 4,000 kg elephant that is running at 2 m/s? at 4 m/s? How do the two kinetic energies compare with one another?
3. What is the kinetic energy of a 2,000 kg bus that is moving at 30 m/s?
4. What is the kinetic energy of a 3,000 kg bus that is moving at 20 m/s?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 3 *The stored potential energy of the bow and string allows them to do work on the arrow when the string is released.*

Potential Energy

Not all energy has to do with motion. **Potential energy** is the energy an object has because of its position. For example, the stretched bow shown in **Figure 3** has potential energy. The bow has energy because work has been done to change its shape. The energy of that work is turned into potential energy.

Gravitational Potential Energy

When you lift an object, you do work on it. You use a force that is against the force of gravity. When you do this, you transfer energy to the object and give the object *gravitational potential energy.* Books on a shelf have gravitational potential energy. So does your backpack after you lift it on to your back. The amount of gravitational potential energy that an object has depends on its weight and its height.

Calculating Gravitational Potential Energy

You can find gravitational potential energy by using the following equation:

$$\textit{gravitational potential energy} = \textit{weight} \times \textit{height}$$

Because weight is expressed in newtons and height in meters, gravitational potential energy is expressed in newton-meters (N•m), or joules (J).

Recall that *work* = *force* × *distance*. Weight is the amount of force that you must use on an object to lift it, and height is a distance. So, gravitational potential energy is equal to the amount of work done on the object to lift it to a certain height. Or, you can think of gravitational potential energy as equal to the work that would be done by the object if it were dropped from its height.

MATH FOCUS

Gravitational Potential Energy What is the gravitational potential energy of a book with a weight of 13 N at a height of 1.5 m off the ground?

Step 1: Write the equation for gravitational potential energy (*GPE*).

$$GPE = weight \times height$$

Step 2: Replace the weight and height with the measurements given in the problem, and solve.

$$GPE = 13\ \text{N} \times 1.5\ \text{m}$$

$$GPE = 19.5\ \text{N•m} = 19.5\ \text{J}$$

Now It's Your Turn

1. What is the gravitational potential energy of a cat that weighs 40 N standing on a table that is 0.8 m above the ground?
2. What is the gravitational potential energy of a diver who weighs 500 N standing on a platform that is 10 m off the ground?
3. What is the gravitational potential energy of a diver who weighs 600 N standing on a platform that is 8 m off the ground?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Height Above What?

When you want to find out an object's gravitational potential energy, the "ground" that you measure the object's height from depends on where it is. For example, what if you want to measure the gravitational potential energy of an egg sitting on the kitchen counter? In this case, you would measure the egg's height from the floor. But if you were holding the egg over a balcony several stories from the ground, you would measure the egg's height from the ground! You can see that gravitational potential energy depends on your point of view. So, the height you use in calculating gravitational potential energy is a measure of how far an object has to fall.

potential energy the energy that an object has because of the position, shape, or condition of the object

mechanical energy the amount of work an object can do because of the object's kinetic and potential energies

Mechanical Energy

How would you describe the energy of the juggler's pins in **Figure 4**? To describe their total energy, you would state their mechanical energy. **Mechanical energy** is the total energy of motion and position of an object. Both potential energy and kinetic energy are kinds of mechanical energy. Mechanical energy can be all potential energy, all kinetic energy, or some of each. You can use the following equation to find mechanical energy:

mechanical energy = potential energy + kinetic energy

Reading Check **What two kinds of energy can make up the mechanical energy of an object?**

Mechanical Energy in a Juggler's Pin

The mechanical energy of an object remains the same unless it transfers some of its energy to another object. But even if the mechanical energy of an object stays the same, the potential energy or kinetic energy it has can increase or decrease.

Look at **Figure 4.** While the juggler is moving the pin with his hand, he is doing work on the pin to give it kinetic energy. But as soon as the pin leaves his hand, the pin's kinetic energy starts changing into potential energy. How can you tell that the kinetic energy is decreasing? The pin slows down as it moves upwards. Eventually, all of the pin's kinetic energy turns into potential energy, and it stops moving upward.

As the pin starts to fall back down again, its potential energy starts changing back into kinetic energy. More and more of its potential energy turns into kinetic energy. You can tell because the pin speeds up as it falls towards the ground.

Figure 4 *As a pin is juggled, its mechanical energy is the sum of its potential energy and its kinetic energy at any point.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 5 **Thermal Energy in Water**

The particles in an ice cube vibrate in fixed positions and do not have a lot of kinetic energy.

The particles of water in a lake can move more freely and have more kinetic energy than water particles in ice do.

The particles of water in steam move rapidly, so they have more energy than the particles in liquid water do.

Other Forms of Energy

Energy can come in a number of forms besides mechanical energy. These forms of energy include thermal, chemical, electrical, sound, light, and nuclear energy. As you read the next few pages, you will learn what these different forms of energy have to do with kinetic and potential energy.

Thermal Energy

All matter is made of particles that are always in random motion. Because the particles are in motion, they have kinetic energy. *Thermal energy* is all of the kinetic energy due to random motion of the particles that make up an object.

As you can see in **Figure 5,** particles move faster at higher temperatures than at lower temperatures. The faster the particles move, the greater their kinetic energy and the greater the object's thermal energy. Thermal energy also depends on the number of particles. Water in the form of steam has a higher temperature than water in a lake does. But the lake has more thermal energy because the lake has more water particles.

INTERNET ACTIVITY

For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HP5ENGW.**

Chemical Energy

Where does the energy in food come from? Food is made of chemical compounds. When compounds such as sugar form, work is done to join the different atoms together. *Chemical energy* is the energy of a compound that changes as its atoms are rearranged. Chemical energy is a form of potential energy because it depends on the position and arrangement of the atoms in a compound.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Quick Lab

Hear That Energy!

1. Make a simple drum by covering the open end of an **empty coffee can** with **wax paper.** Secure the wax paper with a **rubber band.**
2. Using the eraser end of a **pencil,** tap lightly on the wax paper. Describe how the paper responds. What do you hear?
3. Repeat step 2, but tap the paper a bit harder. Compare your results with those of step 2.
4. Cover half of the wax paper with one hand. Now, tap the paper. What happened? How can you describe sound energy as a form of mechanical energy?

Electrical Energy

The electrical outlets in your home allow you to use electrical energy. *Electrical energy* is the energy of moving electrons. Electrons are the negatively charged particles of atoms.

Suppose you plug an electrical device, such as the amplifier shown in **Figure 6,** into an outlet and turn it on. The electrons in the wires will transfer energy to different parts inside the amplifier. The electrical energy of moving electrons is used to do work that makes the sound that you hear from the amplifier.

The electrical energy used in your home comes from power plants. Huge generators turn magnets inside loops of wire. The changing position of a magnet makes electrical energy run through the wire. This electrical energy can be thought of as potential energy that is used when you plug in an electrical appliance and use it.

Figure 6 *The movement of electrons produces the electrical energy that an amplifier and a microphone use to produce sound.*

Sound Energy

Figure 7 shows how a vibrating object transmits energy through the air around it. Sound energy is caused by an object's vibrations. When you stretch a guitar string, the string stores potential energy. When you let the string go, this potential energy is turned into kinetic energy, which makes the string vibrate. The string also transmits some of this kinetic energy to the air around it. The air particles also vibrate, and transmit this energy to your ear. When the sound energy reaches your ear, you hear the sound of the guitar.

Reading Check **What does sound energy consist of?**

Figure 7 *As the guitar strings vibrate, they cause particles in the air to vibrate. These vibrations transmit sound energy.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 8 *The energy used to cook food in a microwave is a form of light energy.*

Light Energy

Light allows you to see, but did you know that not all light can be seen? **Figure 8** shows a type of light that we use but can't see. *Light energy* is produced by the vibrations of electrically charged particles. Like sound vibrations, light vibrations cause energy to be transmitted. But the vibrations that transmit light energy don't need to be carried through matter. In fact, light energy can move through a vacuum (an area where there is no matter).

Nuclear Energy

There is a form of energy that comes from a tiny amount of matter. It is used to generate electrical energy, and it gives the sun its energy. It is *nuclear* (NOO klee uhr) *energy*, the energy that comes from changes in the nucleus (NOO klee uhs) of an atom.

Atoms store a lot of potential energy because of the positions of the particles in the nucleus of the atoms. When two or more small nuclei (NOO klee ie) join together, or when the nucleus of a large atom splits apart, energy is given off.

The energy given off by the sun comes from nuclear energy. In the sun, shown in **Figure 9,** hydrogen nuclei join together to make a larger helium nucleus. This reaction, known as *fusion,* gives off a huge amount of energy. The sun's light and heat come from these reactions.

When a nucleus of a heavy element such as uranium is split apart, the potential energy in the nucleus is given off. This kind of nuclear energy is called *fission*. Fission is used to generate electrical energy at nuclear power plants.

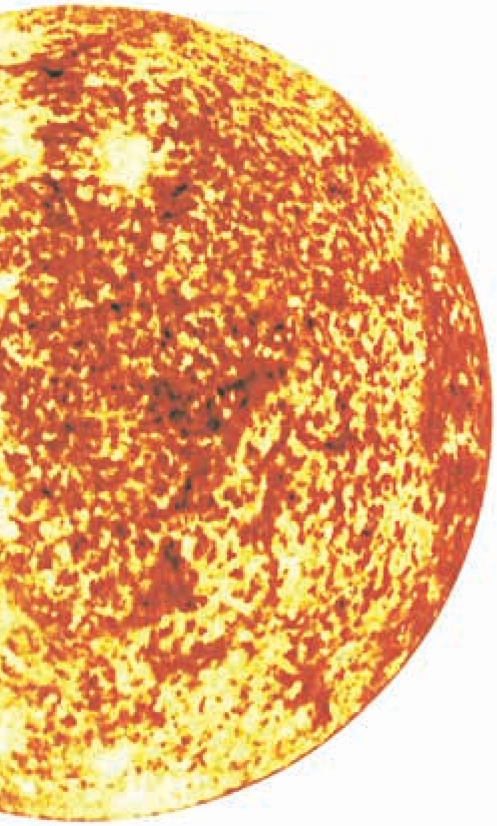


Figure 9 *Without the nuclear energy from the sun, life on Earth would not be possible.*

Reading Check **Where does nuclear energy come from?**

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION Review

Summary

- Energy is the ability to do work, and work equals the transfer of energy. Energy and work are expressed in units of joules (J).
- Kinetic energy is energy of motion and depends on speed and mass.
- Potential energy is energy of position. Gravitational potential energy depends on weight and height.
- Mechanical energy is the sum of kinetic energy and potential energy.
- Thermal energy and sound energy can be considered forms of kinetic energy.
- Chemical energy, electrical energy, and nuclear energy can be considered forms of potential energy.

Using Key Terms

1. In your own words, write a definition for the term *energy*.
2. Use the following terms in the same sentence: *kinetic energy, potential energy,* and *mechanical energy*.

Understanding Key Ideas

3. What determines an object's thermal energy?
   a. the motion of its particles
   b. its size
   c. its potential energy
   d. its mechanical energy
4. How are energy and work related?
5. What two factors determine gravitational potential energy?
6. Describe why chemical energy is a form of potential energy.

Critical Thinking

7. **Identifying Relationships** When you hit a nail into a board by using a hammer, the head of the nail gets warm. In terms of kinetic and thermal energy, describe why you think the nail head gets warm.
8. **Applying Concepts** Explain why a high-speed collision may cause more damage to vehicles than a low-speed collision does.

Interpreting Graphics

9. Which part of mechanical energy does the girl in the picture below have the most of?

SCILINKS® NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: What Is Energy? ; Forms of Energy
SciLinks code: HSM1660; HSM0612

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 2

Energy Conversions

Imagine you're finishing a clay mug in art class. You turn around, and your elbow knocks the mug off the table. Luckily, you catch the mug before it hits the ground.

READING WARM-UP

Objectives

- Describe an energy conversion.
- Give examples of energy conversions for the different forms of energy.
- Explain how energy conversions make energy useful.
- Explain the role of machines in energy conversions.

Terms to Learn

energy conversion

READING STRATEGY

Brainstorming The key idea of this section is energy conversion. Brainstorm words and phrases related to energy conversion.

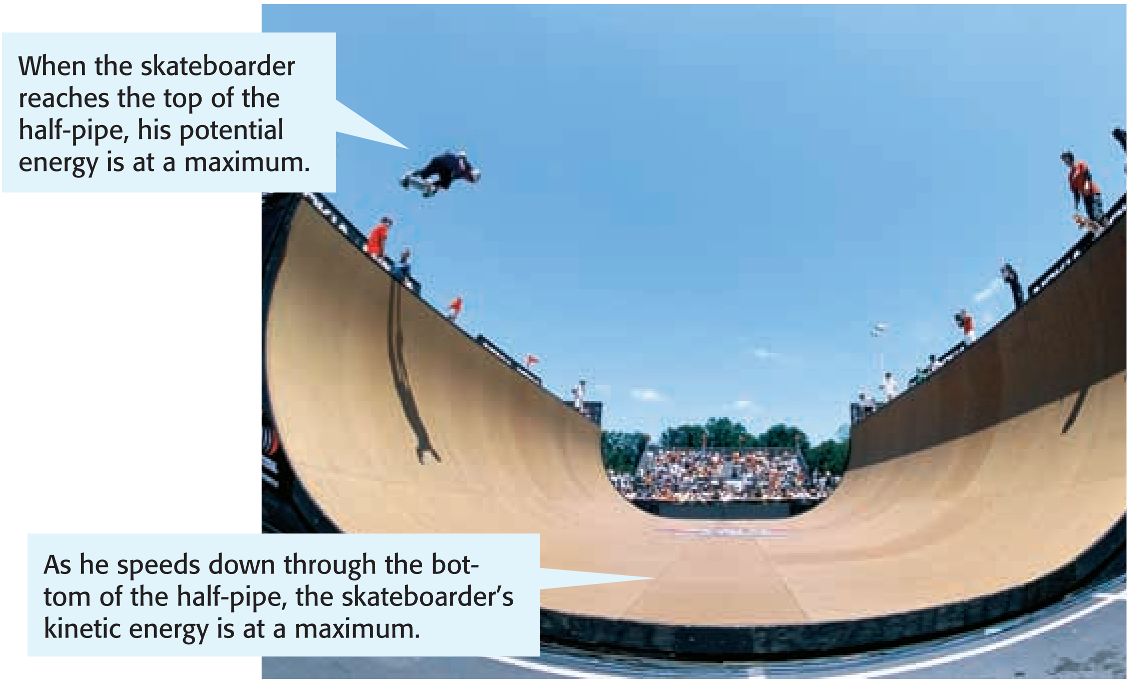
The mug has gravitational potential energy while it is on the table. As the mug falls, its potential energy changes into kinetic energy. This change is an example of an energy conversion. An **energy conversion** is a change from one form of energy to another. Any form of energy can change into any other form of energy. Often, one form of energy changes into more than one other form.

energy conversion a change from one form of energy to another

Kinetic Energy and Potential Energy

Look at **Figure 1.** At the instant this picture was taken, the skateboarder on the left side of the picture was hardly moving. How did he get up so high in the air? As you might guess, he was moving at a high speed on his way up the half-pipe. So, he had a lot of kinetic energy. What happened to that energy? His kinetic energy changed into potential energy. Imagine that the picture below is a freeze-frame of a video. What happens once the video starts running again? The skateboarder's potential energy will become kinetic energy once again as he speeds down the side of the half-pipe.

Figure 1 Potential Energy and Kinetic Energy



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Elastic Potential Energy

A rubber band can be used to show another example of an energy conversion. Did you know that energy can be stored in a rubber band? Look at **Figure 2.** The wound-up rubber band in the toy airplane has a kind of potential energy called *elastic potential energy*. When the rubber band is let go, the stored energy becomes kinetic energy, spins the propeller, and makes the airplane fly.

You can change the shape of a rubber band by stretching it. Stretching the rubber band takes a little effort. The energy you put into stretching it becomes elastic potential energy. Like the skateboarder at the top of the half-pipe, the stretched rubber band stores potential energy. When you let the rubber band go, it goes back to its original shape. It releases its stored-up potential energy as it does so, as you know if you have ever snapped a rubber band against your skin!

Reading Check **How is elastic potential energy stored and released?** (*See the Appendix for answers to Reading Checks.*)

Figure 2 *The wound-up rubber band in this model airplane has potential energy because its shape has been changed.*

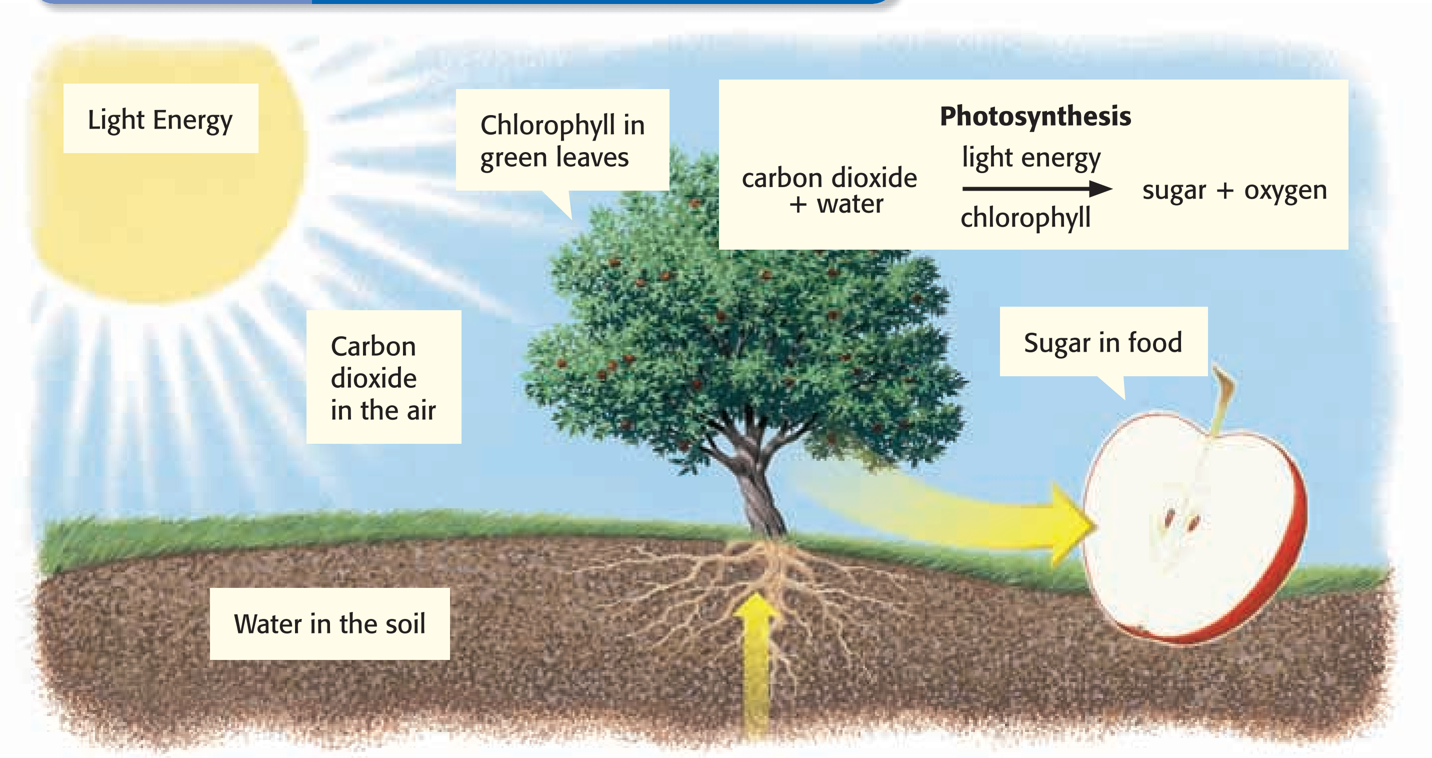
Conversions Involving Chemical Energy

You may have heard someone say, "Breakfast is the most important meal of the day." Why is eating breakfast so important? As shown in **Figure 3,** chemical energy comes from the food you eat. Your body uses chemical energy to function. Eating breakfast gives your body the energy needed to help you start the day.

Figure 3 Chemical energy of food is converted into kinetic energy when you are active. It is converted into thermal energy to maintain body temperature.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 4 **From Light Energy to Chemical Energy**



Energy Conversions in Plants

Did you know that the chemical energy in the food you eat comes from the sun's energy? When you eat fruits, vegetables, or grains, you are taking in chemical energy. This energy comes from a chemical change that was made possible by the sun's energy. When you eat meat from animals that ate plants, you are also taking in energy that first came from the sun.

As shown in **Figure 4,** photosynthesis (FOHT oh SIN thuh sis) uses light energy to make new substances that have chemical energy. In this way, light energy is changed into chemical energy. The chemical energy from a tree can be changed into thermal energy when you burn the tree's wood. So, if you follow the conversion of energy back far enough, the energy from a wood fire actually comes from the sun!

Reading Check **Where does the energy that plants use to grow come from?**

CONNECTION TO Biology

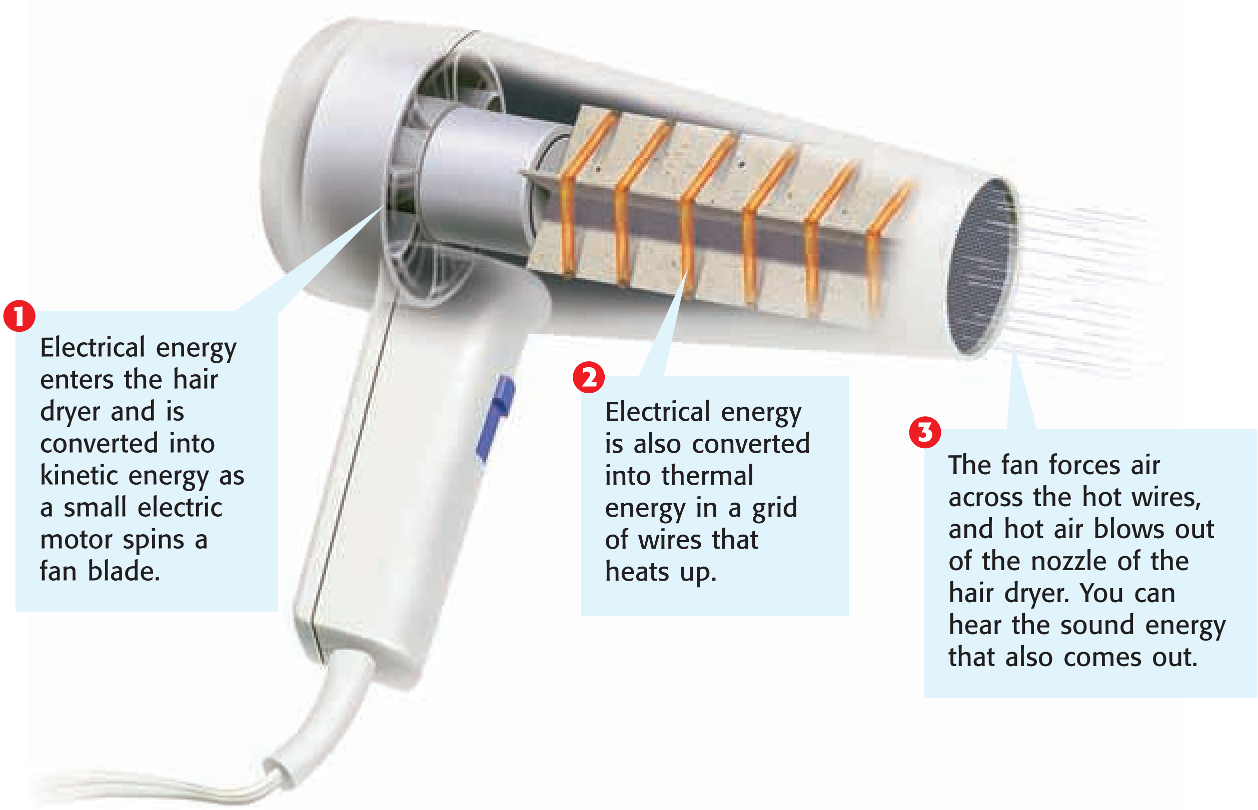
WRITING SKILL **Energy from Plants** All living things need energy. Plants play a major role in providing sources of energy that our bodies use, from the oxygen we breathe to the food we eat. Research the different ways that plants help provide the energy requirements of all living things, and write a one-page report in your **science journal** describing what you learn.

The Process Continues

Let's trace where the energy goes. Plants change light energy into chemical energy. The chemical energy in the food you eat is changed into another kind of chemical energy that your body can use. Your body then uses that energy to give you the kinetic energy that you use in everything you do. It's an endless process—energy is always going somewhere!

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 5 **Energy Conversions in a Hair Dryer**



Why Energy Conversions Are Important

Energy conversions are needed for everything we do. Heating our homes, getting energy from a meal, and many other things use energy conversions. Machines, such as the hair dryer shown in **Figure 5,** help harness energy and make that energy work for you. Electrical energy by itself won't dry your hair. But you can use a hair dryer to change electrical energy into the thermal energy that will help you dry your hair.

Conversions Involving Electrical Energy

You use electrical energy all of the time. When you listen to the radio, when you make toast, and when you take a picture with a camera, you use electrical energy. Electrical energy can easily be changed into other forms of energy. **Table 1** lists some common energy conversions that involve electrical energy.

Table 1 Some Conversions of Electrical Energy	
Alarm clock	electrical energy → light energy and sound energy
Battery	chemical energy → electrical energy
Light bulb	electrical energy → light energy and thermal energy
Blender	electrical energy → kinetic energy and sound energy

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 6 *Some of the energy you transfer to a nutcracker is converted into sound energy as the nutcracker transfers energy to the nut.*

Energy and Machines

You've been learning about energy, its different forms, and the ways that it can change between forms. Another way to learn about energy is to look at how machines use energy. A machine can make work easier by changing the size or direction (or both) of the force needed to do the work.

Suppose you want to crack open a walnut. Using a nutcracker, such as the one shown in **Figure 6,** would be much easier (and less painful) than using your fingers. You transfer energy to the nutcracker, and it transfers energy to the nut. The nutcracker allows you to use less force over a greater distance to do the same amount of work as if you had used your bare hands. Another example of how energy is used by a machine is shown in **Figure 7.** Some machines change the energy put into them into other forms of energy.

Reading Check **What are two things that machines can do to force that is put into them?**

Figure 7 **Energy Conversions in a Bicycle**

For your bike to start and keep moving, energy must be transferred and converted.

1. Chemical energy in your body is converted into kinetic energy when your muscle fibers contract and relax.
2. Your legs transfer this kinetic energy to the pedals by pushing them around in a circle.
3. The pedals transfer this kinetic energy to the gear wheel, which transfers kinetic energy to the chain.
4. The chain moves and transfers energy to the back wheel, which gets you moving!

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Machines as Energy Converters

Machines help you use energy by converting it into the form that you need. **Figure 8** shows a device called a *radiometer*. It was invented to measure energy from the sun. Inside the glass bulb are four small vanes that absorb light energy. The vanes are dark on one side and light on the other. The dark sides absorb light energy better than the light sides do. As gases next to the dark sides of the vanes heat up, the gas molecules move faster, which causes the vanes to turn. The radiometer shows how a machine can convert energy from one form into another. It changes light energy into heat energy into kinetic energy.

Figure 8 *Machines can change energy into different forms. This radiometer converts light energy into kinetic energy.*

SECTION Review

Summary

- An energy conversion is a change from one form of energy to another. Any form of energy can be converted into any other form of energy.
- Kinetic energy is converted to potential energy when an object is moved against gravity.
- Elastic potential energy is another example of potential energy.
- Your body uses the food you eat to convert chemical energy into kinetic energy.
- Plants convert light energy into chemical energy.
- Machines can transfer energy and can convert energy into a more useful form.

Using Key Terms

1. In your own words, write a definition for the term *energy conversion*.

Understanding Key Ideas

2. In plants, energy is transformed from
   a. kinetic to potential.
   b. light to chemical.
   c. chemical to electrical.
   d. chemical to light.
3. Describe a case in which electrical energy is converted into thermal energy.
4. How does your body get the energy that it needs?
5. What is the role of machines in energy conversions?

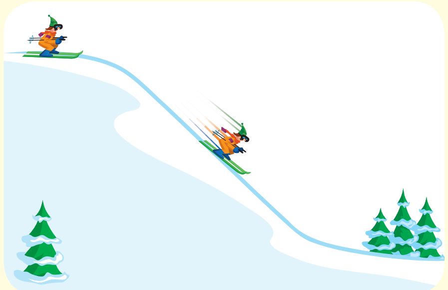
Critical Thinking

6. **Applying Concepts** Describe the kinetic-potential energy conversions that occur when a basketball bounces.
7. **Applying Concepts** A car that brakes suddenly comes to a screeching halt. Is the sound energy produced in this conversion a useful form of energy? Explain your answer.

Interpreting Graphics

Look at the diagram below, and answer the following questions.

8. What kind of energy does the skier have at the top of the slope?
9. What happens to that energy after the skier races down the slope of the mountain?



SCILINKS® NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Energy Conversions
SciLinks code: HSM0511

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 3

Conservation of Energy

Many roller coasters have a mechanism that pulls the cars up to the top of the first hill. But the cars are on their own for the rest of the ride.

As the cars go up and down the hills on the track, their potential energy is converted into kinetic energy and back again. But the cars never return to the same height at which they started. Does energy get lost somewhere along the way? No, it is just converted into other forms of energy.

READING WARM-UP

Objectives

- Explain how energy is conserved within a closed system.
- Explain the law of conservation of energy.
- Give examples of how thermal energy is always a result of energy conversion.
- Explain why perpetual motion is impossible.

Terms to Learn

friction
law of conservation of energy

READING STRATEGY

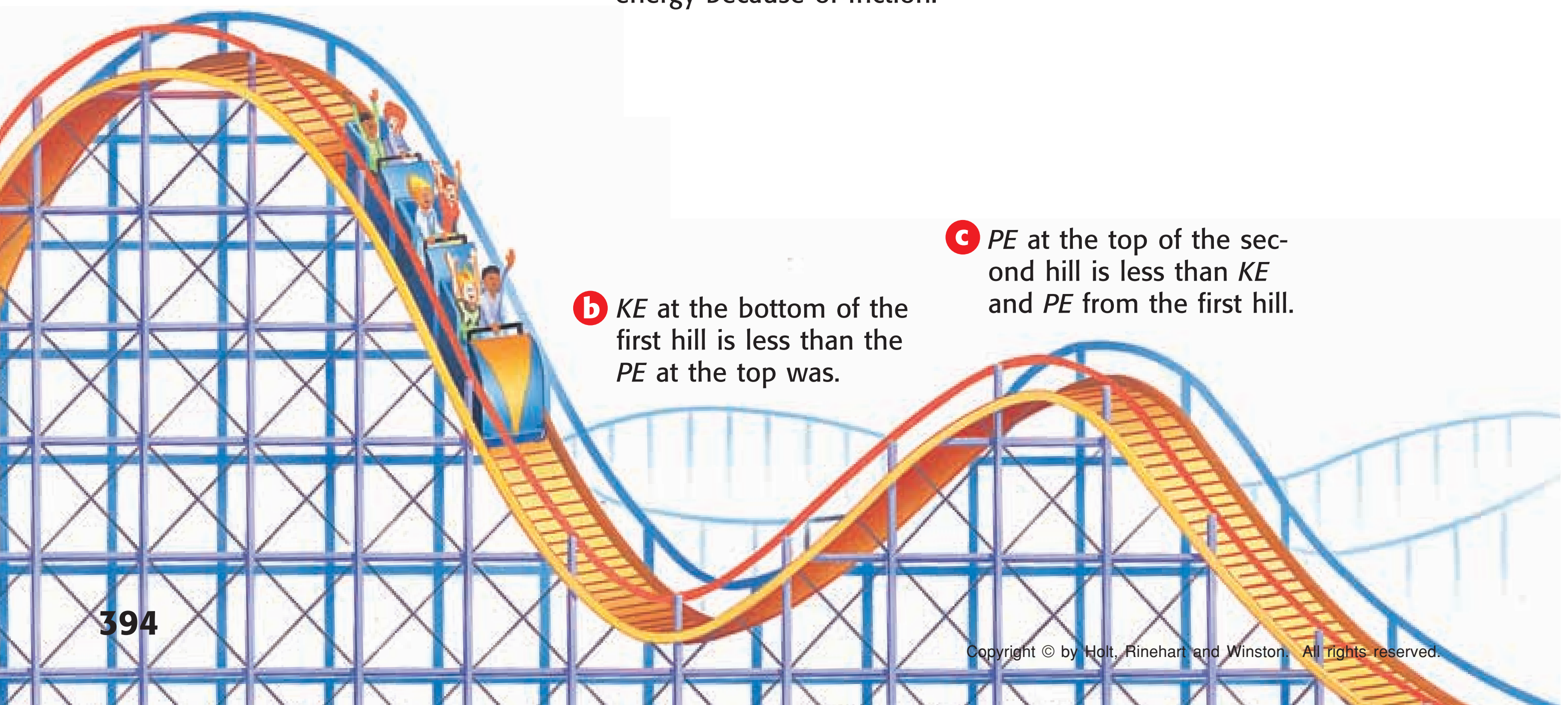
Paired Summarizing Read this section silently. In pairs, take turns summarizing the material. Stop to discuss ideas that seem confusing.

Where Does the Energy Go?

To find out where a roller coaster's original potential energy goes, you have to think about more than just the hills of the roller coaster. Friction plays a part too. **Friction** is a force that opposes motion between two surfaces that are touching. For the roller coaster to move, energy must be used to overcome friction. There is friction between the cars' wheels and the track and between the cars and the air around them. As a result, not all of the potential energy of the cars changes into kinetic energy as the cars go down the first hill. Likewise, as you can see in **Figure 1,** not all of the kinetic energy of the cars changes back into potential energy.

Figure 1 **Energy Conversions in a Roller Coaster**

Not all of the cars' potential energy (*PE*) is converted into kinetic energy (*KE*) as the cars go down the first hill. In addition, not all of the cars' kinetic energy is converted into potential energy as the cars go up the second hill. Some of it is changed into thermal energy because of friction.



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Energy Is Conserved Within a Closed System

A *closed system* is a group of objects that transfer energy only to each other. For example, a closed system that involves a roller coaster consists of the track, the cars, and the air around them. On a roller coaster, some mechanical energy (the sum of kinetic and potential energy) is always converted into thermal energy because of friction. Sound energy also comes from the energy conversions in a roller coaster. If you add together the cars' kinetic energy at the bottom of the first hill, the thermal energy due to overcoming friction, and the sound energy made, you end up with the same total amount of energy as the original amount of potential energy. In other words, energy is conserved and not lost.

friction a force that opposes motion between two surfaces that are in contact

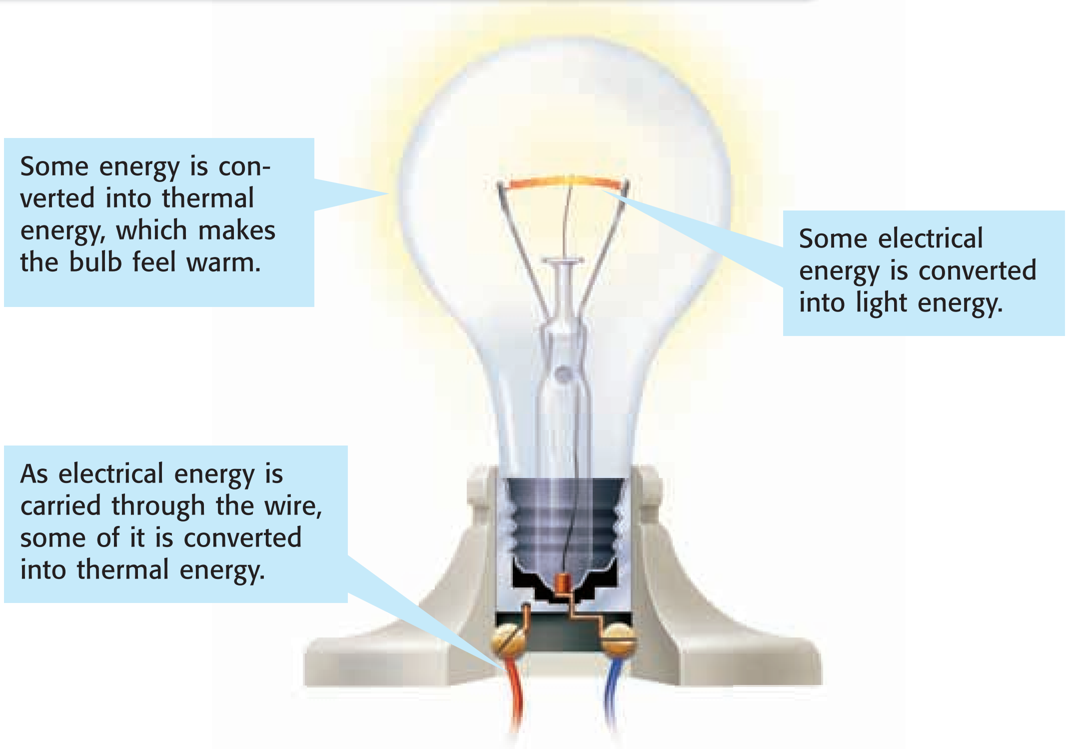
law of conservation of energy the law that states that energy cannot be created or destroyed but can be changed from one form to another

Law of Conservation of Energy

Energy is conserved in all cases. Because no exception to this rule has been found, this rule is described as a law. According to the **law of conservation of energy,** energy cannot be created or destroyed. The total amount of energy in a closed system is always the same. As **Figure 2** shows, energy can change from one form to another. But all of the different forms of energy in a system always add up to the same total amount of energy. It does not matter how many energy conversions take place.

Reading Check **Why is the conservation of energy considered a scientific law?** (*See the Appendix for answers to Reading Checks.*)

Figure 2 **Energy Conservation in a Light Bulb**



Copyright © by Holt, Rinehart and Winston. All rights reserved.

No Conversion Without Thermal Energy

Any time one form of energy is converted into another form, some of the original energy always gets converted into thermal energy. The thermal energy due to friction that results from energy conversions is not useful energy. That is, this thermal energy is not used to do work. Think about a car. You put gas into a car. But not all of the gasoline's chemical energy makes the car move. Some wasted thermal energy will always result from the energy conversions. Much of this energy leaves through the radiator and the exhaust pipe.

SCHOOL to HOME

Energy Conversions

With a parent, find three examples of energy conversions that take place in your home. In your **science journal,** write down the kinds of energy that go into each conversion and the kinds of energy that result. For each type of energy that is output, indicate whether the energy is useful.

ACTIVITY

Perpetual Motion? No Way!

People have sometimes tried to make a machine that would run forever without any additional energy. This perpetual (puhr PECH oo uhl) motion machine would put out exactly as much energy as it takes in. But that's impossible, because some waste thermal energy always results from energy conversions. The only way a machine can keep moving is to have a constant supply of energy. For example, the "drinking bird" shown in **Figure 3** uses thermal energy from the air to evaporate the water from its head. So, it is not a perpetual motion machine.

✓ *Reading Check* **Why is "perpetual motion" impossible?**

Figure 3 **The "Drinking Bird"**

1. When the bird "drinks," the felt covering its head gets wet.
2. When the bird is upright, water evaporates from the felt, which decreases the temperature and pressure in the head. Fluid is drawn up from the tail, where pressure is higher, and the bird tips downward.
3. After the bird "drinks," fluid returns to the tail, the bird flips upright, and the cycle repeats.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

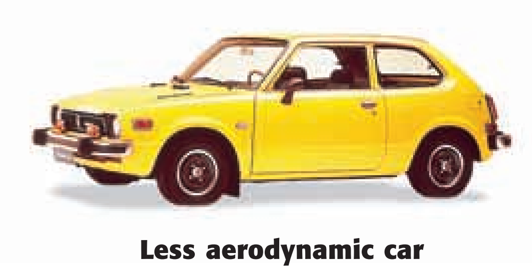
Making Conversions Efficient

Some systems transform energy with less loss of heat than others do. Such systems are more efficient than others are. You may have heard that a car is energy efficient if it gets good gas mileage. In terms of energy conversions, *energy efficiency* (e FISH uhn see) is a comparison of the amount of energy before a conversion with the amount of useful energy after a conversion. The difference in energy is often thermal energy due to friction. Keeping moving parts oiled reduces friction in and loss of heat from a system.

Newer cars tend to be more energy efficient than older cars. One reason is the smooth, aerodynamic (ER oh die NAM ik) shape of newer cars, as shown in **Figure 4.** Because these cars move through air more easily, they use less energy to overcome friction. So, they are more efficient. Improving the efficiency of machines, such as cars, is important because greater efficiency results in less waste. If less energy is wasted, less energy is needed to operate a machine.

Figure 4 *The shape of newer cars reduces friction between the body of the car and the air.*

More aerodynamic car



Less aerodynamic car

SECTION Review

Summary

- Because of friction, some energy is always converted into thermal energy during an energy conversion.
- Energy is conserved within a closed system. According to the law of conservation of energy, energy cannot be created or destroyed.
- Perpetual motion is impossible because some of the energy put into a machine is converted into thermal energy because of friction.

Using Key Terms

1. Use the following terms in the same sentence: *friction* and *the law of conservation of energy.*

Understanding Key Ideas

2. Perpetual motion is impossible because
   a. things tend to slow down.
   b. energy is lost.
   c. machines are very inefficient.
   d. machines have friction.
3. Describe the energy conversions that take place on a roller coaster, and explain how energy is conserved.

Math Skills

4. A bike is pedaled with 80 J of energy and then coasts. It does 60 J of work in moving forward until it stops. How much of the energy that was put into the bike became thermal energy?

Critical Thinking

5. **Evaluating Conclusions** Imagine that you drop a ball. It bounces a few times and then it stops. Your friend says that the energy that the ball had is gone. Where did the energy go? Evaluate your friend's statement based on energy conservation.
6. **Evaluating Assumptions** If someone says that a car has high energy output, can you conclude that the car is efficient? Explain.

SCILINKS® NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Law of Conservation of Energy
SciLinks code: HSM0856

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 4

Energy Resources

Energy is used to light and warm our homes. It is used to make food, clothing, and other things. It is also used to transport people and products from place to place. Where does all of this energy come from?

READING WARM-UP

Objectives

- Name several energy resources.
- Explain how the sun is the source of most energy on Earth.
- Evaluate the advantages and disadvantages of using various energy resources.

Terms to Learn

nonrenewable resource
fossil fuel
renewable resource

READING STRATEGY

Reading Organizer As you read this section, make a table comparing nonrenewable resources and renewable resources.

An *energy resource* is a natural resource that can be converted into other forms of energy in order to do useful work. In this section, you will learn about several energy resources, including the one that most other energy resources come from—the sun.

Nonrenewable Resources

Some energy resources, called **nonrenewable resources,** cannot be replaced or are replaced much more slowly than they are used. Fossil fuels are the most important nonrenewable resources.

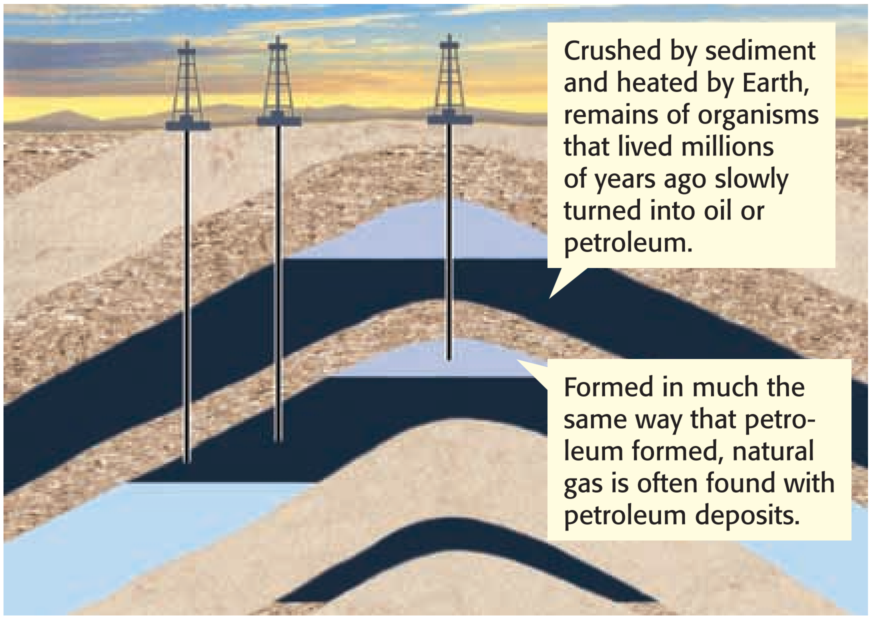
Oil and natural gas, shown in **Figure 1,** as well as coal, are the most common fossil fuels. **Fossil fuels** are energy resources that formed from the buried remains of plants and animals that lived millions of years ago. These plants stored energy from the sun by photosynthesis. Animals used and stored this energy by eating the plants. So, fossil fuels are concentrated forms of the sun's energy. Now, millions of years later, energy from the sun is released when these fossil fuels are burned.

Reading Check **Why are fossil fuels considered nonrenewable resources?** *(See the Appendix for answers to Reading Checks.)*

nonrenewable resource a resource that forms at a rate that is much slower than the rate at which it is consumed

fossil fuel a nonrenewable energy resource formed from the remains of organisms that lived long ago

Figure 1 Formation of Fossil Fuels



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Uses of Fossil Fuels

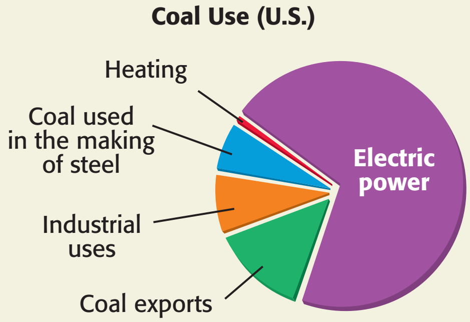
All fossil fuels contain stored energy from the sun, which can be converted into other kinds of energy. **Figure 2** shows some different ways that fossil fuels are used in our society.

People have been getting energy from the burning of coal, a fossil fuel, for hundreds of years. Today, burning coal is still a very common way to generate electrical energy. Many products, such as gasoline, wax, and plastics, are made from petroleum, another fossil fuel. A third kind of fossil fuel, natural gas, is often used in home heating.

Figure 2 Everyday Uses of Some Fossil Fuels

Coal

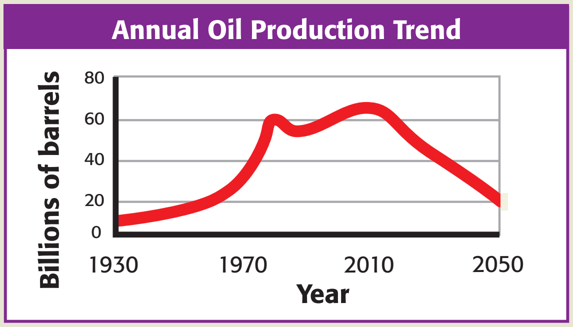
Most coal used in the United States is burned to produce steam to run electric generators.



Petroleum

Gasoline, kerosene, wax, and petrochemicals come from petroleum.

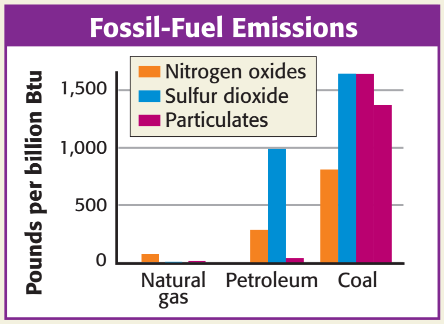
Finding alternative energy resources will become more important in years to come.



Natural Gas

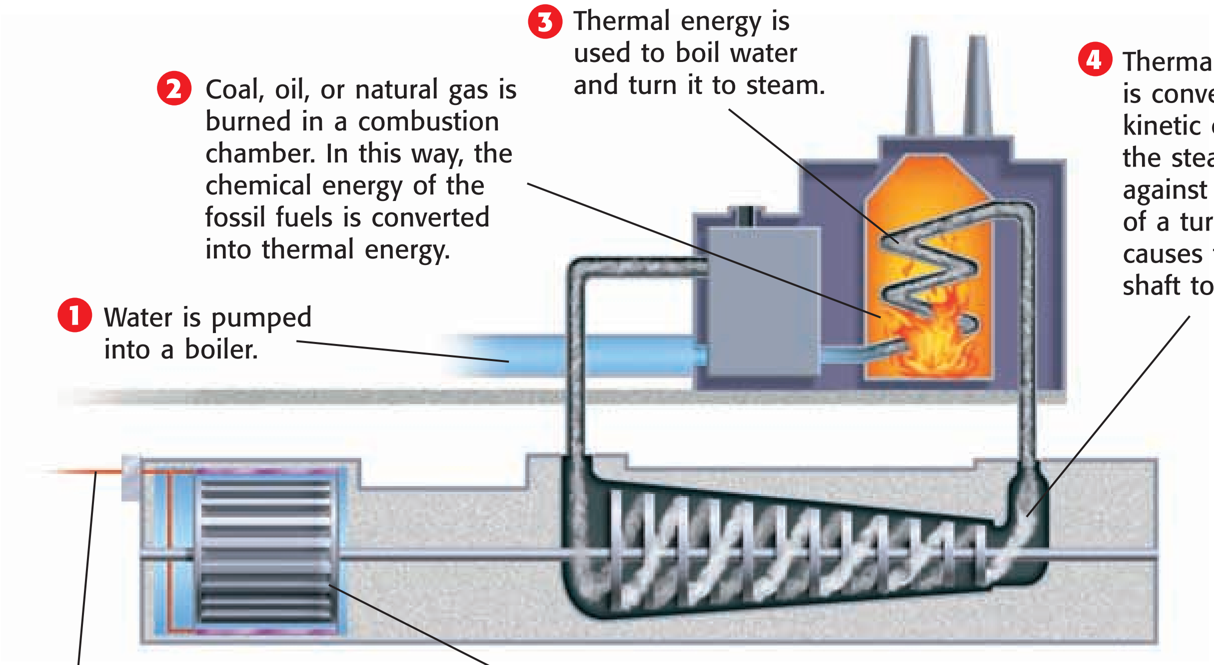
Natural gas is used in heating systems, stoves, ovens, and vehicles.

Compared to other fossil fuels, natural gas has very low emission levels when burned.



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 3 **Converting Fossil Fuels into Electrical Energy**



Electrical Energy from Fossil Fuels

One way to generate electrical energy is to burn fossil fuels. In fact, fossil fuels are the main source of electrical energy generated in the United States. *Electric generators* convert the chemical energy in fossil fuels into electrical energy by the process shown in **Figure 3.** The chemical energy in fossil fuels is changed into the electrical energy that you use every day.

Figure 4 *A single uranium fuel pellet contains the energy equivalent of about 1 metric ton of coal.*

Nuclear Energy

Another way to generate electrical energy is to use nuclear energy. Like fossil-fuel power plants, a nuclear power plant generates thermal energy that boils water to make steam. The steam then turns a turbine, which runs a generator. The spinning generator changes kinetic energy into electrical energy. However, the fuels used in nuclear power plants differ from fossil fuels. Nuclear energy is generated from radioactive elements, such as uranium, shown in **Figure 4.** In a process called *nuclear fission* (NOO klee uhr FISH uhn), the nucleus of a uranium atom is split into two smaller nuclei, which releases nuclear energy. Because the supply of these elements is limited, nuclear energy is a nonrenewable resource.

Reading Check **Where does nuclear energy come from?**

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Renewable Resources

Some energy resources, called **renewable resources,** are naturally replaced more quickly than they are used. Some renewable resources, such as solar energy and wind energy, are considered practically limitless.

renewable resource a natural resource that can be replaced at the same rate at which the resource is consumed

Solar Energy

Sunlight can be changed into electrical energy through solar cells. These cells can be used in devices such as calculators. Solar cells can also be placed on the roof of a house to provide electrical energy. Some houses can use solar energy by allowing sunlight into the house through large windows. The sun's energy can then be used to heat the house.

Figure 5 *This dam converts the energy from water going downstream into electrical energy.*

Energy from Water

The sun causes water to evaporate and fall again as rain that flows through rivers. The potential energy of water in a reservoir can be changed into kinetic energy as the water flows through a dam. **Figure 5** shows a hydroelectric dam. Falling water turns turbines in a dam. The turbines are connected to a generator that changes kinetic energy into electrical energy.

Wind Energy

Wind is caused by the sun's heating of Earth's surface. Because Earth's surface is not heated evenly, wind is created. The kinetic energy of wind can turn the blades of a windmill. Wind turbines are shown in **Figure 6.** A wind turbine changes the kinetic energy of the air into electrical energy by turning a generator.

Figure 6 *These wind turbines are converting wind energy into electrical energy.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Geothermal Energy

Thermal energy caused by the heating of Earth's crust is called *geothermal energy.* Some geothermal power plants pump water underground next to hot rock. The water returns to the surface as steam, which can then turn the turbine of a generator.

Reading Check **Where does geothermal energy come from?**

Biomass

Plants use and store energy from the sun. Organic matter, such as plants, wood, and waste, that can be burned to release energy is called *biomass*. **Figure 7** shows an example. Some countries depend on biomass for energy.

Figure 7 *Plants capture the sun's energy. When wood is burned, it releases the energy it got from the sun, which can be used to generate electrical energy.*

The Two Sides to Energy Resources

All energy resources have advantages and disadvantages. How can you decide which energy resource to use? **Table 1** compares several energy resources. Depending on where you live, what you need energy for, and how much energy you need, one energy resource may be a better choice than another.

***Table 1* Advantages and Disadvantages of Energy Resources**

Energy Resource	Advantages	Disadvantages
Fossil fuels	• provide a large amount of thermal energy per unit of mass • are easy to get and transport • can be used to generate electricity and to make products such as plastic	• is nonrenewable • produces smog • releases substances that can cause acid precipitation • creates a risk of oil spills
Nuclear	• is a very concentrated form of energy • does not produce air pollution	• produces radioactive waste • is nonrenewable
Solar	• is an almost limitless source of energy • does not produce pollution	• is expensive to use for large-scale energy production • is practical only in sunny areas
Water	• is renewable • does not produce air pollution	• requires dams, which disrupt a river's ecosystem • is available only where there are rivers
Wind	• is renewable • is relatively inexpensive to generate • does not produce air pollution	• is practical only in windy areas
Geothermal	• is an almost limitless source of energy • power plants require little land	• is practical only in areas near hot spots • produces wastewater, which can damage soil
Biomass	• is renewable • is inexpensive	• requires large areas of farmland • produces smoke

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Choosing the Right Energy Resource

As **Table 1** shows, each source of energy that we know about on Earth has advantages and disadvantages. For example, you have probably heard that fossil fuels pollute the air. They will also run out after they are used up. Even renewable resources have their drawbacks. Generating lots of energy from solar energy is difficult. So it cannot be used to meet the energy needs of large cities. Geothermal energy is limited to the "hot spots" in the world where it is available. Hydroelectric energy requires large dams, which can affect the ecology of river life. Energy planning in all parts of the world requires careful consideration of energy needs and the availability and responsible use of resources.

CONNECTION TO Social Studies

WRITING SKILL **Earth's Energy Resources** Find examples of places in the world where the various energy resources mentioned in this chapter are used. List them in your **science journal.** Discuss any patterns that you notice, such as which regions of the world use certain energy resources.

SECTION Review

Summary

- An energy resource is a natural resource that can be converted into other forms of energy in order to do useful work.
- Nonrenewable resources cannot be replaced after they are used or can be replaced only after long periods of time. They include fossil fuels and nuclear energy.
- Renewable resources can be replaced in nature over a relatively short period of time. They include energy from the sun, wind, and water; geothermal energy; and biomass.
- The sun is the source of most energy on Earth.
- Choices about energy resources depend on where you live and what you need energy for.

Using Key Terms

1. In your own words, write a definition for the term *fossil fuel*.

Complete each of the following sentences by choosing the correct term from the word bank.

nonrenewable resources
renewable resources

2. There is a practically limitless supply of ___.
3. ___ are used up more quickly than they are being replaced.

Understanding Key Ideas

4. Which of the following is a renewable resource?
   a. wind
   b. coal
   c. nuclear energy
   d. petroleum
5. Compare fossil fuels and biomass as energy resources.
6. Trace electrical energy back to the sun.

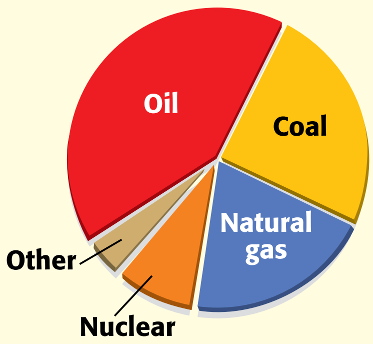
Critical Thinking

7. **Making Comparisons** Describe the similarities and differences between transforming energy in a hydroelectric dam and a wind turbine.
8. **Analyzing Ideas** Name an energy resource that does NOT depend on the sun.

Interpreting Graphics

9. Use the pie chart below to explain why renewable resources are becoming more important to the United States.

U.S. Energy Sources



SCILINKS NSTA Developed and maintained by the National Science Teachers Association

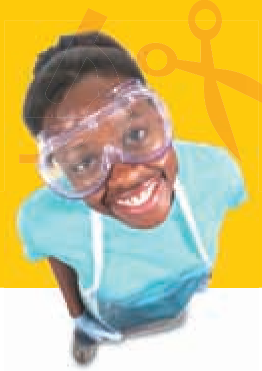
For a variety of links related to this chapter, go to www.scilinks.org

Topic: Energy Resources
SciLinks code: HSM0515

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Using Scientific Methods

Skills Practice Lab



Finding Energy

When you coast down a hill on a bike or skateboard, you may notice that you pick up speed, or go faster and faster. Because you are moving, you have kinetic energy—the energy of motion. Where does that energy come from? When you pedal the bike or push the skateboard, you are the source of the kinetic energy. But where does the kinetic energy come from when you roll down a hill without making any effort? In this lab, you will find out where such kinetic energy comes from.

OBJECTIVES

Form a hypothesis about where kinetic energy comes from.

Test your hypothesis by collecting and analyzing data.

MATERIALS

- books (2 or 3)
- masking tape
- meterstick
- metric balance
- rolling cart
- stopwatch
- wooden board

Ask a Question

1. Where does the kinetic energy come from when you roll down a hill?

Form a Hypothesis

2. Write a hypothesis that is a possible answer to the question above. Explain your reasoning.

Test the Hypothesis

3. Copy the Data Collection Table below.

Data Collection Table

Height of ramp (m)	Length of ramp (m)	Mass of cart (kg)	Weight of cart (N)	Time of trial (s)			Average time (s)
				1	2	3	
		DO NOT WRITE IN BOOK					

Copyright © by Holt, Rinehart and Winston. All rights reserved.

4. Use your books and board to make a ramp.
5. Use masking tape to mark a starting line at the top of the ramp. Be sure the starting line is far enough down from the top of the ramp to allow the cart to be placed behind the line.
6. Use masking tape to mark a finish line at the bottom of the ramp.
7. Find the height of the ramp by measuring the height of the starting line and subtracting the height of the finish line. Record the height of the ramp in your Data Collection Table.
8. Measure the distance in meters between the starting line and the finish line. In the Data Collection Table, record this distance as the length of the ramp.
9. Use the balance to find the mass of the cart in grams. Convert this measurement to kilograms by dividing it by 1,000. In your Data Collection Table, record the mass in kilograms.
10. Multiply the mass by 10 to get the weight of the cart in newtons. Record this weight in your Data Collection Table.
11. Set the cart behind the starting line, and release it. Use a stopwatch to time how long the cart takes to reach the finish line. Record the time in your Data Collection Table.
12. Repeat step 11 twice more, and average the results. Record the average time in your Data Collection Table.

Analyze the Results

1. **Organizing Data** Copy the Calculations Table shown at right onto a separate sheet of paper.
2. **Analyzing Data** Calculate and record the quantities for the cart in the Calculations Table by using your data and the four equations that follow.

Calculations Table

Average speed (m/s)	Final speed (m/s)	Kinetic energy at bottom (J)	Gravitational potential energy at top (J)
DO NOT WRITE IN BOOK			

$$\textit{average speed} = \frac{\textit{length of ramp}}{\textit{average time}}$$

Final speed = 2 × *average speed*
(This equation works because the cart accelerates smoothly from 0 m/s.)

$$\textit{kinetic energy} = \frac{\textit{mass} \times (\textit{final speed})^2}{2}$$

(Remember that 1 kg • m^2/s^2 = 1 J, the unit used to express energy.)

Gravitational potential energy =
weight × *height*
(Remember that 1 N = 1 kg • m/s^2,
so 1 N × 1 m = 1 kg • m^2/s^2 = 1 J)

Draw Conclusions

3. **Drawing Conclusions** How does the cart's gravitational potential energy at the top of the ramp compare with its kinetic energy at the bottom? Does this support your hypothesis? Explain your answer.
4. **Evaluating Data** You probably found that the gravitational potential energy of the cart at the top of the ramp was almost, but not exactly, equal to the kinetic energy of the cart at the bottom of the ramp. Explain this finding.
5. **Applying Conclusions** Suppose that while riding your bike, you coast down both a small hill and a large hill. Compare your final speed at the bottom of the small hill with your final speed at the bottom of the large hill. Explain your answer.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Chapter Review

USING KEY TERMS

For each pair of terms, explain how the meanings of the terms differ.

1. *potential energy* and *kinetic energy*
2. *mechanical energy* and *energy conversion*
3. *friction* and *the law of conservation of energy*
4. *renewable resources* and *nonrenewable resources*
5. *energy resources* and *fossil fuels*

UNDERSTANDING KEY IDEAS

Multiple Choice

6. Kinetic energy depends on
   a. mass and volume.
   b. velocity and weight.
   c. weight and height.
   d. velocity and mass.

7. Gravitational potential energy depends on
   a. mass and velocity.
   b. weight and height.
   c. mass and weight.
   d. height and distance.

8. Which of the following types of energy is not a renewable resource?
   a. wind energy
   b. nuclear energy
   c. solar energy
   d. geothermal energy

9. Which of the following sentences describes a conversion from chemical energy to thermal energy?
   a. Food is digested and used to regulate body temperature.
   b. Charcoal is burned in a barbecue pit.
   c. Coal is burned to produce steam.
   d. All of the above

10. When energy changes from one form to another, some of the energy always changes into
    a. kinetic energy.
    b. potential energy.
    c. thermal energy.
    d. mechanical energy.

Short Answer

11. Name two forms of energy, and relate them to kinetic or potential energy.

12. Give three examples of one form of energy being converted into another form.

13. Explain what a closed system is, and how energy is conserved within it.

14. How are fossil fuels formed?

Math Skills

15. A box has 400 J of gravitational potential energy.
    a. How much work had to be done to give the box that energy?
    b. If the box weighs 100 N, how far above the ground is it?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

CRITICAL THINKING

16 **Concept Mapping** Use the following terms to create a concept map: *energy, machines, sound energy, hair dryer, electrical energy, energy conversions, thermal energy,* and *kinetic energy*.

17 **Applying Concepts** Describe what happens in terms of energy when you blow up a balloon and release it.

18 **Identifying Relationships** After you coast down a hill on your bike, you will eventually come to a complete stop. Use this fact to explain why perpetual motion is impossible.

19 **Predicting Consequences** Imagine that the sun ran out of energy. What would happen to our energy resources on Earth?

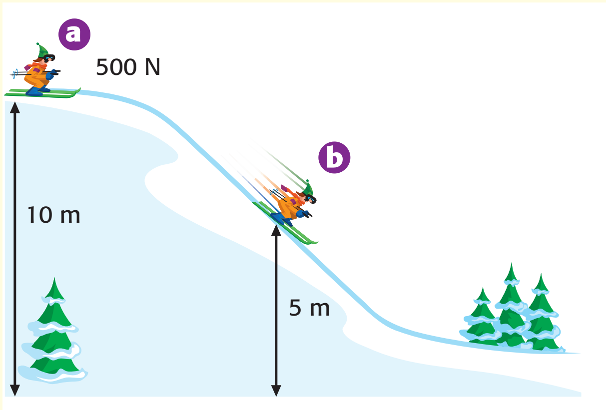
20 **Analyzing Processes** Look at the photo below. Beginning with the pole vaulter's breakfast, trace the energy conversions necessary for the event shown to take place.

21 **Forming Hypotheses** Imagine two cars, one of which is more efficient than the other. Suggest two possible reasons one car is more efficient.

22 **Evaluating Hypotheses** Describe how you would test the two hypotheses you proposed in item 21. How would you determine whether one, both, or neither hypothesis is a factor in the car's efficiency?

INTERPRETING GRAPHICS

Use the graphic below to answer the questions that follow.

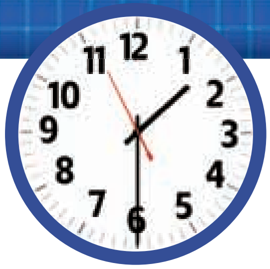


23 What is the skier's gravitational potential energy at point *A*?

24 What is the skier's gravitational potential energy at point *B*?

25 What is the skier's kinetic energy at point *B*? (Hint: mechanical energy = potential energy + kinetic energy)

Copyright © by Holt, Rinehart and Winston. All rights reserved.



Standardized Test Preparation

EOG Prep

READING

Read each of the passages below. Then, answer the questions that follow each passage.

Passage 1 Gas hydrates are icy formations of water and methane. Methane is the main component of natural gas. The methane in gas hydrates is made by bacteria in the ocean. Large areas of hydrates have been found off the coasts of North Carolina and South Carolina in marine sediments. In just two areas that are each about the size of Rhode Island, scientists think there may be 70 times the amount of natural gas used by the United States in 1 year. The energy from gas hydrates could be used to drive machinery or generate electrical energy.

1. How large are each of the two gas hydrate deposits mentioned in this article?

A about the size of the United States
B about the size of South Carolina
C about the size of North Carolina
D about the size of Rhode Island

2. What are gas hydrates mainly made of?

F bacteria and sediments
G water and methane
H natural gas and water
I ice and sediments

3. How long could U.S. natural gas needs be met by all the gas in both deposits mentioned?

A 1 year
B 2 years
C 70 years
D 140 years

4. Where do methane gas hydrates come from?

F ocean water
G bacteria
H sediments
I ice

Passage 2 Two new technologies may reduce the price of electric cars. One is called a *hybrid electric vehicle*. This vehicle has a small gasoline engine that provides extra power and recharges the batteries. The other technology uses hydrogen fuel cells instead of batteries. These cells use the hydrogen present in more-conventional fuels, such as gasoline or ethanol, to produce an electric current that powers the car.

1. In this passage, what does *vehicle* mean?

A electric
B hybrid
C car
D current

2. Which of the following are conventional fuels?

F gasoline and ethanol
G hydrogen and ethanol
H gasoline and hydrogen
I only hydrogen

3. Which of the following is a fact in this passage?

A A hybrid electric vehicle runs partly on gasoline.
B All electric cars are hybrid.
C All electric cars use hydrogen fuel cells.
D Hydrogen fuel cells use conventional fuel.

4. What do the two new technologies described in the passage have in common?

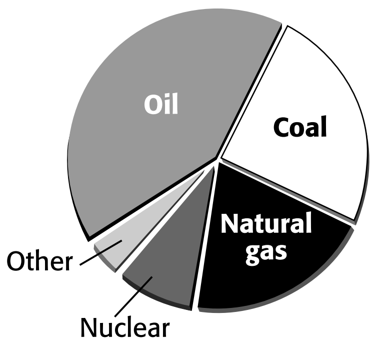
F They do not use conventional fuels.
G They may reduce the price of electric cars.
H They use hybrid engines.
I They use hydrogen to produce an electric current.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

INTERPRETING GRAPHICS

The pie chart below shows U.S. energy use by source of energy. Use the chart below to answer the questions that follow.

U.S. Energy Sources



1. According to the graph, the United States relies on fossil fuels for about what percentage of its energy?

A 30%
B 45%
C 60%
D 80%

2. Nuclear energy represents about what percentage of U.S. energy sources?

F 15%
G 30%
H 50%
I 70%

3. Which energy source accounts for about 25% of U.S. energy?

A oil
B coal
C natural gas
D nuclear energy

MATH

Read each question below, and choose the best answer.

1. Gerald bought 2.5 kg of apples. How many grams of apples did he buy?

A 0.0025 g
B 0.25 g
C 25 g
D 2,500 g

2. Which group contains ratios that are equivalent to 3/8?

F 6/16, 9/24, 12/32
G 6/16, 12/24, 12/32
H 6/24, 12/32, 15/40
I 6/9, 9/24, 15/40

3. Carmen went to a bookstore. She bought three books for $7.99 each and four books for $3.35 each. Which number sentence can be used to find *c*, the total cost of the books?

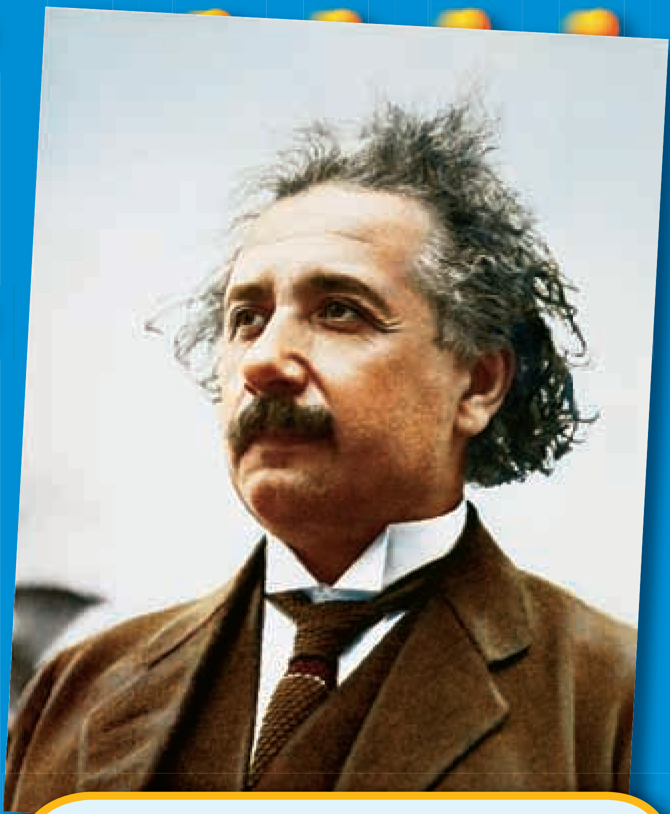
A $c = 3 + (7.99 \times 1) + (4 \times 3.35)$
B $c = (1 \times 7.99) + (3 \times 3.35)$
C $c = (3 \times 7.99) + (4 \times 3.35)$
D $c = (3 \times 7.99) \times (4 \times 3.35)$

4. Rhonda's Mobile Car Washing charges $15 to wash a customer's car. Vacuuming the car costs an extra $10. Rhonda wants to know how much money she earned last week. When she looks at her appointment book, Rhonda finds that she washed a total of 50 cars. Only 20 of these cars were vacuumed after being washed. How much money did Rhonda earn last week?

F $500
G $750
H $950
I $1050

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Science in Action



Science, Technology, and Society

Underwater Jet Engines

Almost all boats that have engines use propellers. But in 2002, a British company announced that it had developed an underwater jet engine.

The underwater jet engine works by producing steam in a gasoline-powered boiler. When the steam hits the water, it condenses to a very small volume, which creates a vacuum. This vacuum causes thrust by sucking in water from the front of the tube. The underwater jet engine is extremely energy-efficient, produces a great amount of thrust, and creates very little pollution.

Social Studies ACTIVITY

Research the kinds of water propulsion people have used throughout history. Note which kinds were improvements on previous technology and which were completely new.

Scientific Discoveries

$E = mc^2$

The famous 20th-century scientist Albert Einstein discovered an equation that is almost as famous as he is. That equation is $E = mc^2$. You may have heard of it before. But what does it mean?

The equation represents a relationship between mass and energy. E represents energy, m represents mass, and c represents the speed of light. So, $E = mc^2$ means that a small amount of mass has a very large amount of energy! Nuclear reactors harness this energy, which is given off when radioactive atoms split.

Math ACTIVITY

The speed of light is approximately 300,000,000 m/s. How much energy is equivalent to the mass of 0.00000002 g of hydrogen?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

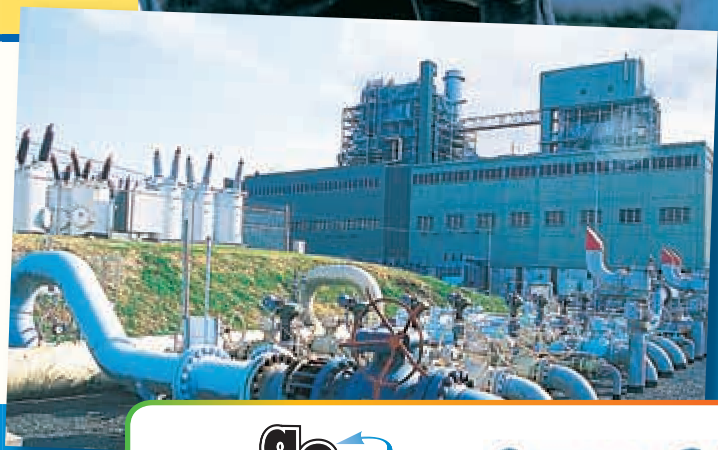
Careers

Cheryl Mele

Power-Plant Manager Cheryl Mele is the manager of the Decker Power Plant in Austin, Texas, where she is in charge of almost 1 billion watts of electric power generation. Most of the electric power is generated by a steam-driven turbine system that uses natural gas fuel. Gas turbines are also used. Together, the systems make enough electrical energy for many homes and businesses.

Cheryl Mele says her job as plant manager is to do "anything that needs doing." Her training as a mechanical engineer allows her to run tests and to find problems in the plant. Previously, Mele had a job helping to design more-efficient gas turbines. That job helped prepare her for the job of plant manager.

Mele believes that engineering and power-plant management are interesting jobs because they allow you to work with many new technologies. Mele thinks young people should pursue what interests them. "Be sure to connect the math you learn to the science you are doing," she says. "This will help you to understand both."



Language Arts ACTIVITY

Look up the word *energy* in a dictionary. Compare the different definitions you find to the definition given in this chapter.

go.hrw.com

To learn more about these Science in Action topics, visit **go.hrw.com** and type in the keyword **HP5ENGF.**

Current Science

Check out Current Science® articles related to this chapter by visiting go.hrw.com. Just type in the keyword HP5CS09.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

14

Temperature and Heat

About the PHOTO

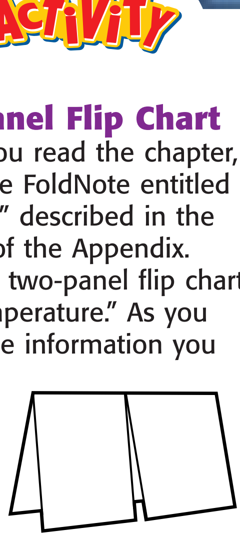
This ice climber is using a lot of special equipment. This equipment includes a rope, a safety helmet, an ice pick, and warm clothing. The climber's clothing, which includes insulating layers inside a protective outer layer, keeps his body heat from escaping into the cold air. If he weren't wearing enough protective clothing, he would be feeling very cold, because thermal energy always moves into areas of lower temperature.

PRE-READING ACTIVITY

FOLDNOTES

Two-Panel Flip Chart

Before you read the chapter, create the FoldNote entitled "Two-Panel Flip Chart" described in the **Study Skills** section of the Appendix. Label the flaps of the two-panel flip chart with "Heat" and "Temperature." As you read the chapter, write information you learn about each category under the appropriate flap.



Copyright © by Holt, Rinehart and Winston. All rights reserved.

START-UP ACTIVITY

Some Like It Hot

Sometimes, you can estimate an object's temperature by touching the object. In this activity, you will find out how well your hand works as a thermometer!

Procedure

1. Gather small pieces of the following materials: **metal, wood, plastic foam, rock, plastic,** and **cardboard.** Allow the materials to sit untouched on a table for a few minutes.
2. Put the palms of your hands on each of the materials. List the materials in order from coolest to warmest.
3. Place a **thermometer strip** on the surface of each material. Record the temperature of each material.

Analysis

1. Which material felt the warmest to your hands?
2. Which material had the highest temperature? Was it the same material that felt the warmest?
3. Why do you think some materials felt warmer than others?
4. Was your hand a good thermometer? Explain why or why not.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 1

Temperature

You probably put on a sweater or a jacket when it's cold. Likewise, you probably wear shorts in the summer when it gets hot. But how hot is hot, and how cold is cold?

READING WARM-UP

Objectives

- Describe how temperature relates to kinetic energy.
- Compare temperatures on different temperature scales.
- Give examples of thermal expansion.
- Analyze response to heat to determine the suitability of materials for use in technological design.

Terms to Learn

temperature
thermal expansion
absolute zero

READING STRATEGY

Prediction Guide Before reading this section, write the title of each heading in this section. Next, under each heading, write what you think you will learn.

Knobs on a water faucet are labeled "H" for hot and "C" for cold. But does hot water come out when the hot-water knob is on? You may notice that the water is warm or even cool at first. So are the labels on the knobs wrong? No, because the terms *hot* and *cold* are not scientific terms. To specify how hot or cold something is, you must use temperature.

What Is Temperature?

You probably think of temperature as a measure of how hot or cold something is. But using the terms *hot* and *cold* can be confusing. Imagine that you are outside on a hot day. You step onto a shady porch where a fan is blowing. You think it feels cool there. Then, your friend comes out onto the porch from an air-conditioned house. She thinks it feels warm! Using the word *temperature* instead of words such as *cool* or *warm* avoids confusion. Scientifically, **temperature** is a measure of the average kinetic energy of the particles in an object.

temperature a measure of how hot (or cold) something is; specifically, a measure of the average kinetic energy of the particles in an object

Temperature and Kinetic Energy

All matter is made of atoms or molecules that are always moving, even if it doesn't look like they are. Because the particles are in motion, they have kinetic energy. The faster the particles are moving, the more kinetic energy they have. Look at **Figure 1.** The more kinetic energy the particles of an object have, the higher the temperature of the object is. And that kinetic energy can also be transferred to other objects.

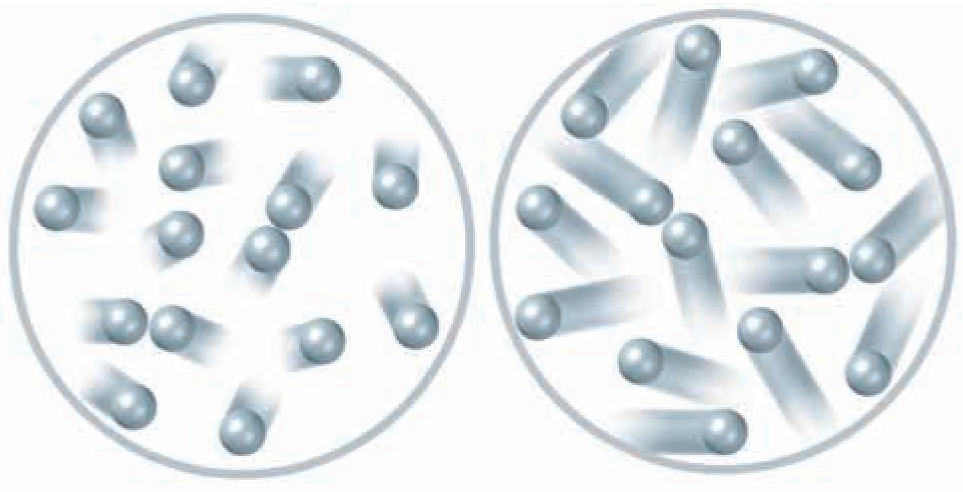


Figure 1 *The gas particles on the right have a higher average kinetic energy than those on the left. So, the gas on the right is at a higher temperature.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Quick Lab

Hot or Cold?

1. Put both your hands into a **bucket of warm water,** and note how the water feels.
2. Now, put one hand into a **bucket of cold water** and the other hand into a **bucket of hot water.**
3. After a minute, take your hands out of the hot and cold water and put them back in the warm water. Note how the water feels to each hand.
4. Can you rely on your hands to determine temperature? Explain your observations.

Internet Activity

For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HP5HOTW.**

Average Kinetic Energy of Particles

Particles of matter are always moving. But they move in different directions and at different speeds. The motion of particles is random. Because particles are moving at different speeds, individual particles have different amounts of kinetic energy. But the *average* kinetic energy of all of the particles in an object can be measured. When you measure an object's temperature, you measure the average kinetic energy of all of the particles in the object.

A substance's temperature depends on the average kinetic energy of all of its particles. Its temperature does not depend on how much of the substance you have. Look at **Figure 2.** A pot of tea and a cup of tea each have a different amount of tea. But their atoms have the same average kinetic energy. So, the pot of tea and the cup of tea are at the same temperature.

Reading Check **How is temperature related to kinetic energy?** (*See the Appendix for answers to Reading Checks.*)

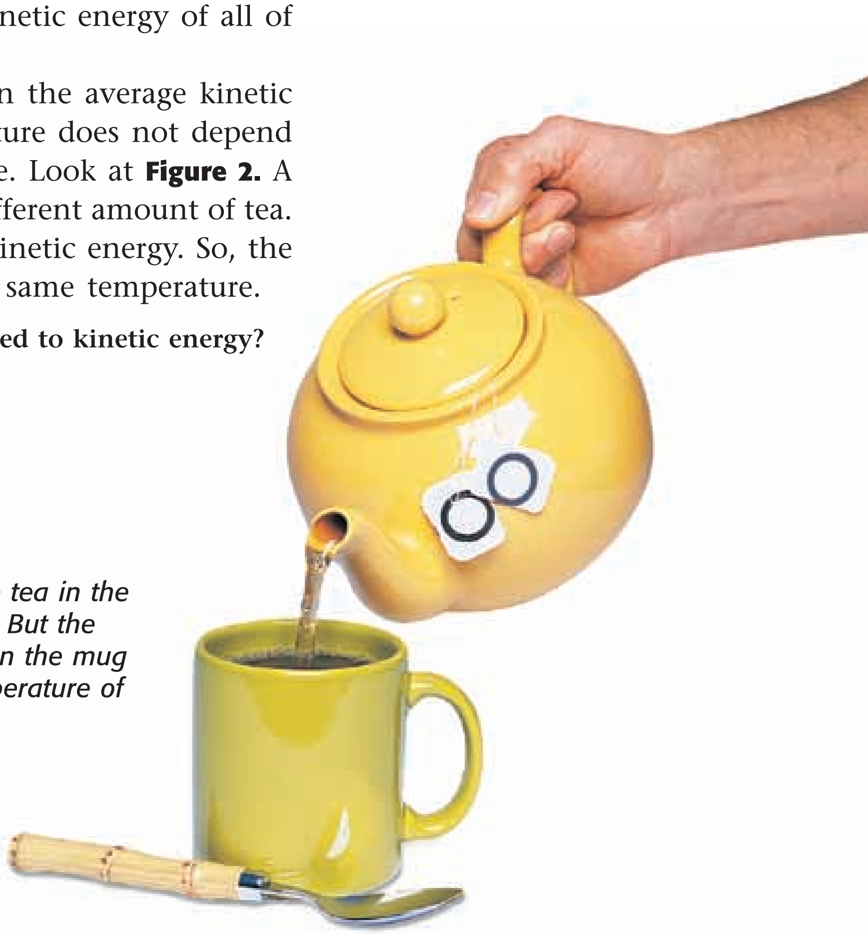


Figure 2 *There is more tea in the teapot than in the mug. But the temperature of the tea in the mug is the same as the temperature of the tea in the teapot.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Measuring Temperature

How would you measure the temperature of a steaming cup of hot chocolate? Would you take a sip of it or stick your finger in it? You probably would not. You would use a thermometer.

Using a Thermometer

Many thermometers are thin glass tubes filled with a liquid. Mercury and alcohol are often used in thermometers because they remain in liquid form over a large temperature range.

Thermometers can measure temperature because of a property called thermal expansion. **Thermal expansion** is the increase in volume of a substance in response to an increase in temperature. As a substance's temperature increases, its particles move faster and spread out. As the space between the particles increases, the substance expands. Mercury and alcohol expand by constant amounts for a given change in temperature.

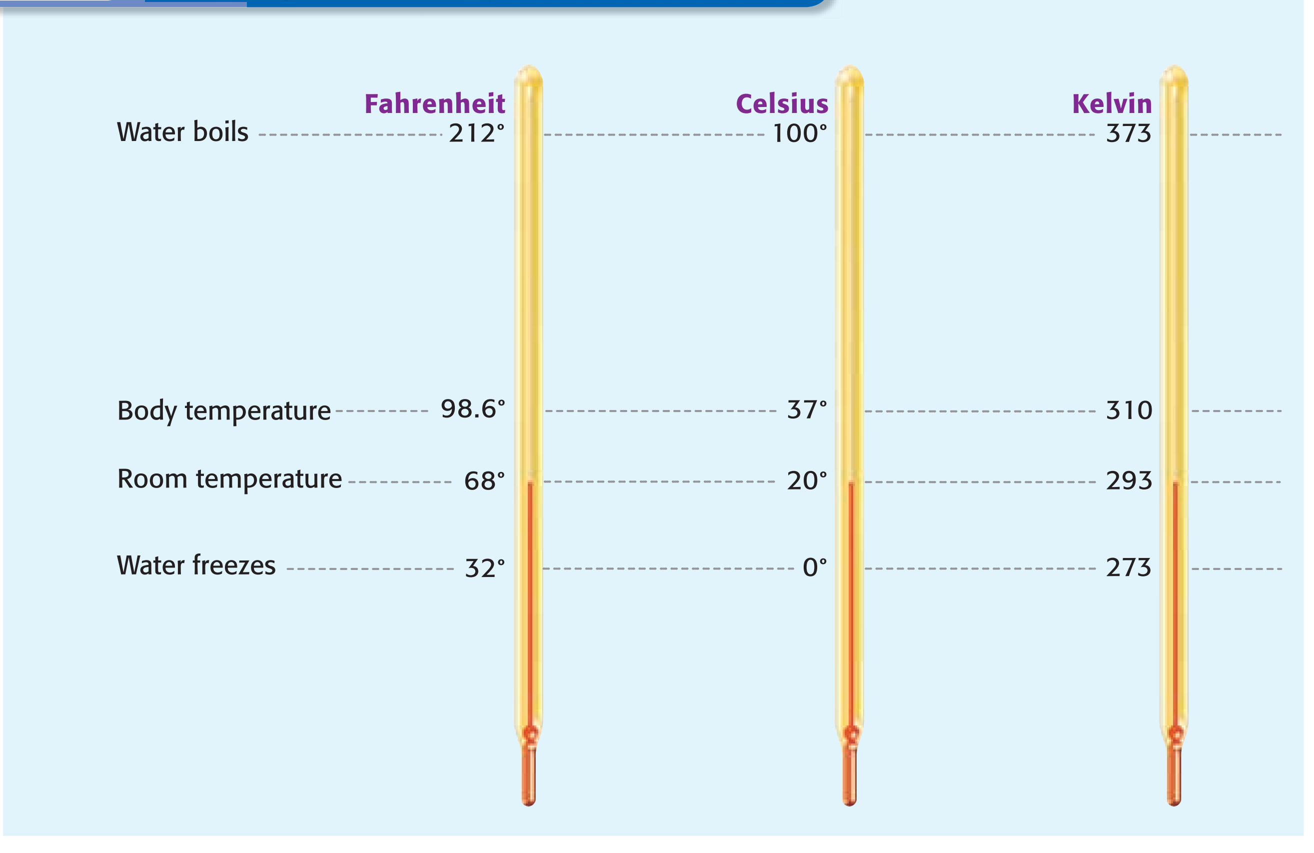
Look at the thermometers in **Figure 3.** They are at the same temperature. So, the alcohol in each thermometer has expanded the same amount. But the number for each thermometer is different because a different temperature scale is marked on each one.

thermal expansion an increase in the size of a substance in response to an increase in the temperature of the substance

absolute zero the temperature at which molecular energy is at a minimum (0 K on the Kelvin scale or −273.16°C on the Celsius scale)

Reading Check **What property makes thermometers work?**

Figure 3 **Three Temperature Scales**



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Temperature Scales

Look at **Figure 4.** When a weather report is given, you will probably hear the temperature given in degrees Fahrenheit (°F). Scientists, however, often use the Celsius scale. In the Celsius scale, the temperature range between the freezing point and boiling point of water is divided into 100 equal parts, called *degrees Celsius* (°C). A third scale, the Kelvin (or absolute) scale, is the official SI temperature scale. The Kelvin scale is divided into units called *kelvins* (K)—not *degrees kelvin*.

The lowest temperature on the Kelvin scale is 0 K, which is called **absolute zero.** Absolute zero (about –459°F) is the temperature at which all molecular motion stops. It is not possible to reach absolute zero, although temperatures very close to 0 K have been reached in laboratories.

Temperature Conversion

As the thermometers on the previous page show, a given temperature is represented by different numbers on the three temperature scales. For example, the freezing point of water is 32°F, 0°C, or 273 K.

The temperature 0°C is actually much higher than 0 K. But a *change* of 1 K is equal to a change of 1°C. The temperature 0°C is higher than 0°F, but a change of 1°F is *not* equal to a change of 1°C. You can convert from one scale to another by using the equations shown in **Table 1** below.

Table 1 Converting Between Temperature Units

To convert	Use the equation	Example
Celsius to Fahrenheit °C → °F	$°F = \left(\frac{9}{5} \times °C\right) + 32$	Convert 45°C to degrees Fahrenheit. $°F = \left(\frac{9}{5} \times 45°C\right) + 32 = 113°F$
Fahrenheit to Celsius °F → °C	$°C = \frac{5}{9} \times (°F - 32)$	Convert 68°F to degrees Celsius. $°C = \frac{5}{9} \times (68°F - 32) = 20°C$
Celsius to Kelvin °C → K	$K = °C + 273$	Convert 45°C to kelvins. $K = 45°C + 273 = 318\ K$
Kelvin to Celsius K → °C	$°C = K - 273$	Convert 32 K to degrees Celsius. $°C = 32\ K - 273 = -241°C$

MATH PRACTICE

Converting Temperatures

Use the equations in **Table 1** to answer the following questions:

1. What temperature on the Celsius scale is equivalent to 373 K?
2. Absolute zero is 0 K. What is the equivalent temperature on the Celsius scale? on the Fahrenheit scale?
3. Which temperature is colder: 0°F or 200 K?

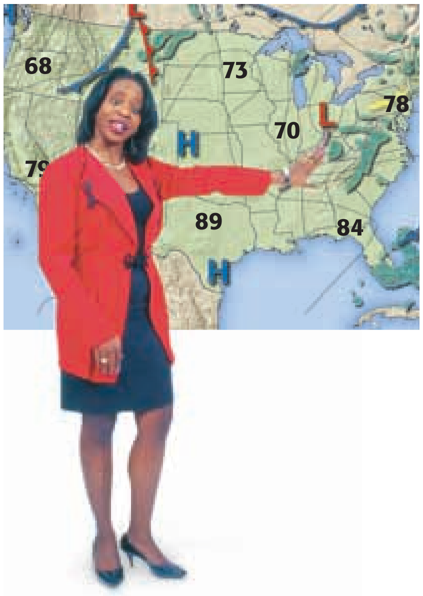


Figure 4 *Weather reports that you see on the news usually give temperatures in degrees Fahrenheit (°F).*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

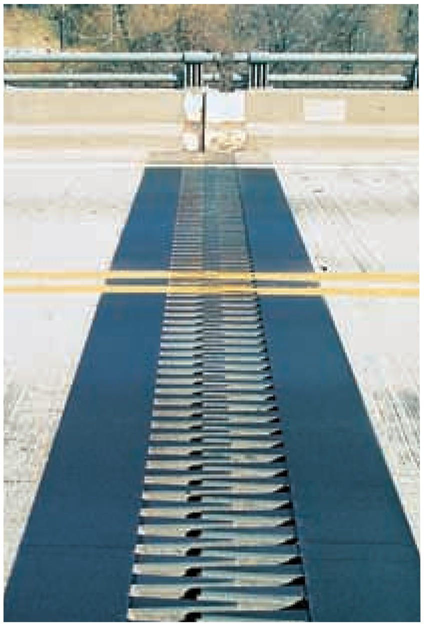


Figure 5 *This gap in the bridge allows the concrete to expand and contract without breaking.*

More About Thermal Expansion

You have learned how thermal expansion works in the liquids that fill thermometers. Thermal expansion has other applications, too. Below, read about a case in which thermal expansion can be dangerous and a case in which it can be useful.

Expansion Joints on Highways

Have you ever gone across a highway bridge in a car? You probably heard and felt a "thuh-thunk" every couple of seconds as you went over the bridge. That sound is made when the car goes over small gaps called *expansion joints,* shown in **Figure 5.** Expansion joints are usually pieces of metal in a strip of asphalt that runs across the bridge.

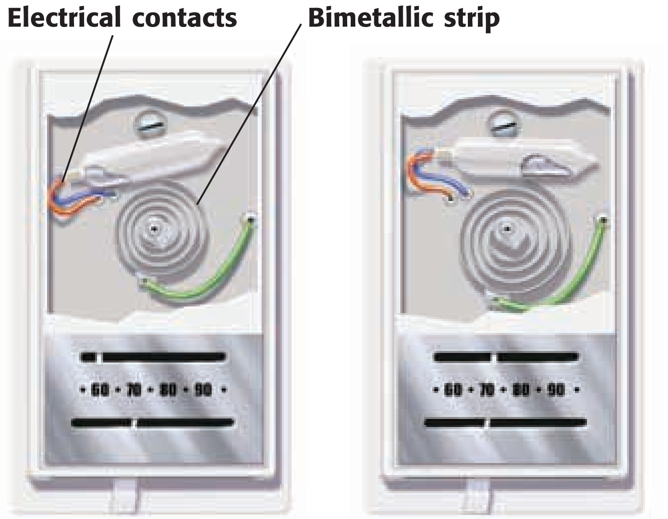
If the weather is very hot, the bridge can heat up enough to expand. As the bridge expands, it is in danger of breaking. Expansion joints keep segments of the bridge apart so that they have room to expand without the bridge breaking.

Reading Check **What is the purpose of expansion joints in a bridge?**

Bimetallic Strips in Thermostats

Thermal expansion also occurs in a thermostat, the device that controls the heater in your home. Some thermostats have a bimetallic strip inside. A *bimetallic strip* is made of two metals stacked in a thin strip. Because different materials expand at different rates, one of the metals expands more than the other when the strip gets hot. As a result, the strip coils and uncoils in response to changes in temperature. This coiling and uncoiling closes and opens an electric circuit that turns the heater on and off in your home, as shown in **Figure 6.**

Figure 6 **How a Thermostat Works**



a As the room temperature drops below the desired level, the bimetallic strip coils more tightly, and the glass tube tilts. A drop of mercury closes an electric circuit that turns the heater on.

b As the room temperature rises above the desired level, the bimetallic strip uncoils slightly and becomes larger. The drop of mercury rolls back in the tube, which opens the electric circuit, and the heater turns off.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 7 *Cast iron is used in skillets because of the way it responds to energy from the burner. Cast iron distributes energy—and cooks food—evenly.*

Temperature and Materials

When you first place an iron skillet, such as the one in **Figure 7,** on the stove, you can touch the metal handle. But after you turn on the burner or element, the metal handle becomes too hot to touch. To pick up the skillet, you have to use a thick cooking glove. Why would anyone choose to use a skillet made of a material that might burn the cook?

Materials and Energy Transfer

Some materials, such as cast iron, transfer, or *conduct,* energy better than other materials do. Cast iron is used for skillets because it conducts energy from the burner to all parts of the skillet—including the handle—evenly. In general, metals conduct energy better than other materials do. So, the steel in bridge expansion joints, the metals in bimetallic strips, and the cast iron in skillets are used because they are suited to the jobs that they are supposed to do.

Solar Heating

Solar heating systems use energy from the sun to heat houses and buildings. Most solar heating systems have certain parts. These parts include clear windows or covers to let in solar energy, dark surfaces inside that soak up energy, materials that prevent energy from escaping, and vents or pipes that carry heated air or liquid from the collector to where it is used. Each part of the system is made of a material that suits its function. For example, special glass is usually used as the cover material. The glass used for solar heating systems is made in such a way to resist breaking and scratching. Although glass does not conduct energy well, it lets the sun's energy through into the collector. Once solar energy warms the air or liquid in the collector, the glass traps the heat inside the collector.

CONNECTION TO Physics

Solar Heating Systems
Solar heating systems are usually classified as active or passive heating systems. Active systems have moving parts. Passive systems have no moving parts. Research solar heating systems of both kinds. Make a poster showing how each system works. Describe the special materials used for each part of the system and their properties.

ACTIVITY

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 8 *Insulation made from fiberglass contains millions of tiny air pockets. Neither the fiberglass nor the air conducts energy very well.*

Materials That Don't Conduct Energy

Cast iron is used in skillets because it is a material suited to what it is supposed to do. But sometimes, materials that do not conduct energy are required. For example, keeping a building warm is important. The fiberglass material, shown in **Figure 8,** can prevent the loss of heat. The fine fibers and air pockets of the material do not conduct energy, so the material is useful in keeping a building warm.

Poor Conductors

In general, nonmetals do not conduct heat very well. Materials such as wood, cardboard, air, cork, fiberglass, and ceramics are poor conductors. *Ceramics* are materials made of nonmetallic minerals. These minerals have been hardened at a high temperature. Because most ceramics are poor conductors of heat, they are used in microwave cookware and dinnerware and in building materials, such as bricks.

Materials and You

To remain alive and healthy, the human body must maintain a temperature of about 37°C. Maintaining this temperature may be difficult in hot summers or cold winters. The challenge of keeping the body temperature stable is even greater for people who live in extreme climates, such as in the Arabian Desert or in the Arctic. People who live in extreme climates wear clothes that help them survive. In hot climates, these clothes are made of lightweight materials that let air circulate next to the skin. Circulating air evaporates sweat, which helps cool the body. In cold climates, clothes are made of materials such as animal skins that trap body heat in pockets of air and prevent energy loss. The hikers in **Figure 9** are wearing clothing that uses the same principle but is made of modern materials.

Figure 9 *These cross-country hikers stay warm by wearing clothes made of lightweight materials that prevent the transfer of energy to the hikers' surroundings.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION Review

Summary

- Temperature is a measure of the average kinetic energy of the particles of a substance.
- The Fahrenheit, Celsius, and Kelvin scales are three temperature scales.
- Thermal expansion is the increase in volume of a substance in response to an increase in temperature.
- Absolute zero (0 K or −273°C) is the lowest possible temperature.
- A material may be chosen for a particular purpose because of the way it responds to heat or cold.
- Some materials, such as metals, conduct energy well.
- Some materials, such as air or ceramics, do not conduct energy well.

Using Key Terms

1. In your own words, write a definition for the term *temperature*.
2. Use each of the following terms in a separate sentence: *thermal expansion* and *absolute zero*.

Understanding Key Ideas

3. Which of the following is the coldest temperature possible?
   - **a.** 0 K
   - **b.** 0°C
   - **c.** 0°F
   - **d.** −273°F
4. Does temperature depend on the amount of the substance? Explain.
5. Describe the process of thermal expansion.
6. What two materials could you use to make a skillet that distributes energy evenly but is safe to pick up without a glove?
7. Why might it be important to have material that does not conduct energy in the walls of a building in both the summer and the winter?

Math Skills

8. Convert 35°C to degrees Fahrenheit.
9. Convert 34°F to degrees Celsius.
10. Convert 0°C to kelvins.
11. Convert 100 K to degrees Celsius.

Critical Thinking

12. **Predicting Consequences** Why do you think heating a full pot of soup on the stove could cause the soup to overflow?
13. **Analyzing Processes** During thermal expansion, what happens to the density of a substance?
14. **Forming Hypotheses** A glass of cold water whose particles had a low average kinetic energy was placed on a table. The average kinetic energy in the cold water increased, while the average kinetic energy of the part of the table under the glass decreased. What do you think happened?
15. **Applying Concepts** On a camping trip, your friend tells you that fluffing up your down sleeping bag before you go to bed will keep you warmer than sleeping in the same bag when it is still crushed from being in its storage sack. Is your friend correct? Explain your answer.

SCILINKS® NSTA
Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: What Is Temperature? Heat Energy
SciLinks code: HSM1664; HSM0727

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 2

What Is Heat?

It's time for your annual physical. The doctor comes in and begins her exam by placing a metal stethoscope on your back. You jump a little and say, "Whoa! That's cold!"

Why does the stethoscope feel cold? The answer has to do with how energy moves between the metal and your skin. In this section, you'll learn about this kind of energy transfer.

READING WARM-UP

Objectives

- Define *heat* as thermal energy transferred between objects at different temperatures.
- Compare conduction, convection, and radiation.
- Use specific heat capacity to calculate heat.

Terms to Learn

heat
thermal energy
thermal equilibrium
thermal conduction
thermal conductor
thermal insulator
convection
radiation
specific heat

READING STRATEGY

Paired Summarizing Read this section silently. In pairs, take turns summarizing the material. Stop to discuss ideas that seem confusing.

Transferred Thermal Energy

You might think of the word *heat* as having to do with things that feel hot. But heat also has to do with things that feel cold—such as the stethoscope. In fact, heat is what causes objects to feel hot or cold or to get hot or cold under the right conditions. You probably use the word *heat* every day to mean different things. However, in this chapter, you will use only one specific meaning for *heat*. **Heat** is the energy transferred between objects that are at different temperatures.

Why do some things feel hot, while others feel cold? When two objects at different temperatures come into contact, energy is always transferred from the object that has the higher temperature to the object that has the lower temperature. Look at **Figure 1.** The doctor's stethoscope touches your back. Energy is transferred from your back to the stethoscope because your back has a higher temperature (about 37°C) than the stethoscope (room temperature, about 20°C) has. This energy is transferred quickly, so the stethoscope feels cold to you.

heat the energy transferred between objects that are at different temperatures

Figure 1 *The metal stethoscope feels cold because of heat!*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Heat and Thermal Energy

Heat is transferred energy. What form of energy is being transferred? The answer is thermal energy. **Thermal energy** is the total kinetic energy of the particles that make up a substance. Thermal energy, which is measured in joules (J), depends partly on temperature. Something at a high temperature has more thermal energy than it would have at a lower temperature. Thermal energy also depends on how much of a substance there is. Look at **Figure 2.** The more particles there are in a substance at a given temperature, the greater the thermal energy of the substance is.

Figure 2 *Although both soups are at the same temperature, there is more soup in the pan. So, the soup in the pan has more thermal energy than the soup in the bowl.*

Reaching Thermal Equilibrium

The point at which two objects that are touching reach the same temperature is called **thermal equilibrium.** When objects at different temperatures come into contact, energy will always be transferred. In **Figure 3,** energy passes from the warmer object (juice) to the cooler object (ice) until both objects have the same temperature. When objects that are touching have the same temperature, no net change in the thermal energy of either one occurs. One object may have more thermal energy than the other one does, but both objects will be at the same temperature, because they have reached thermal equilibrium.

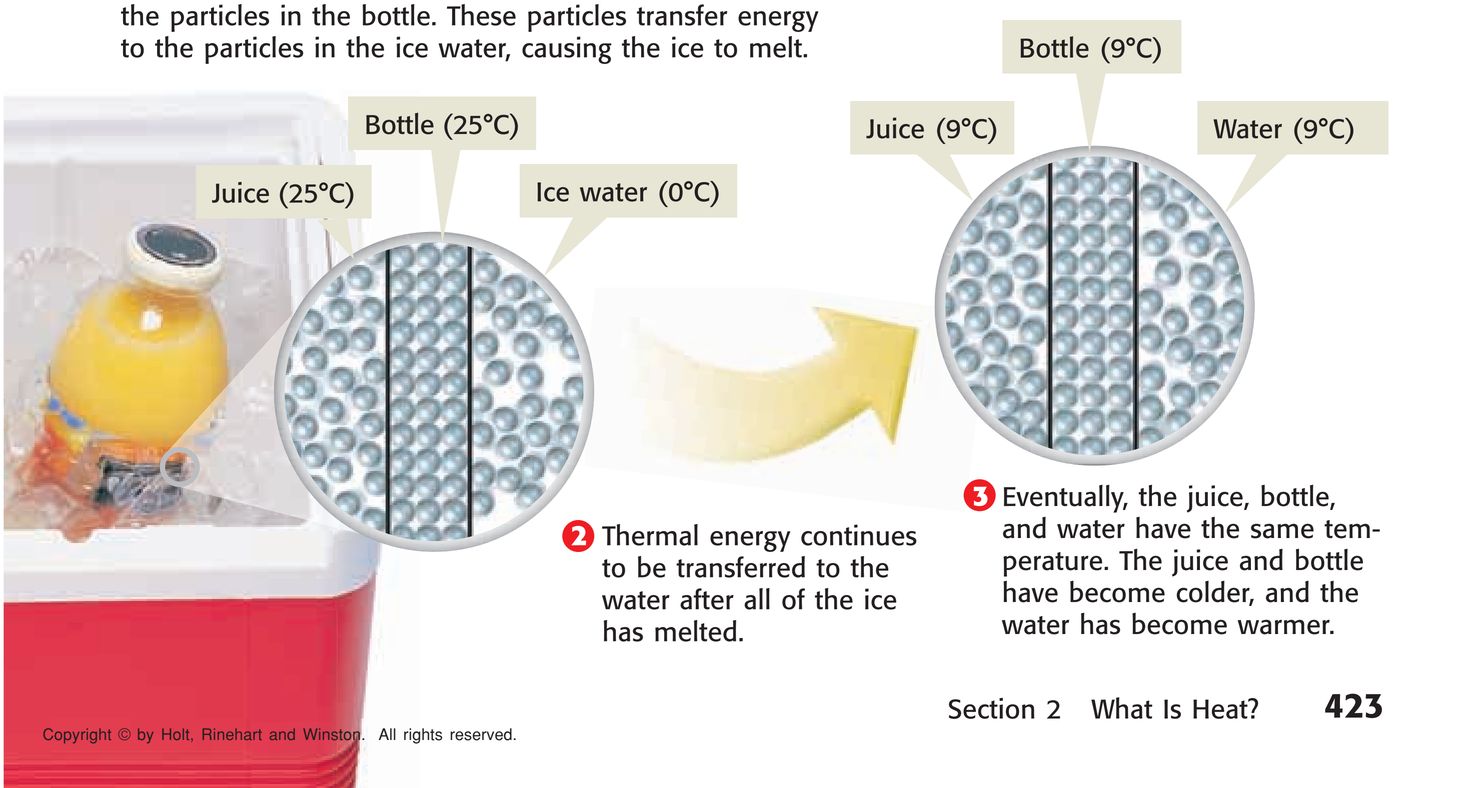
thermal energy the kinetic energy of a substance's atoms

thermal equilibrium the point at which two objects that are touching reach the same temperature

Reading Check **Describe thermal equilibrium.** (*See the Appendix for answers to Reading Checks.*)

Figure 3 Transfer of Thermal Energy

1. Energy is transferred from the particles in the juice to the particles in the bottle. These particles transfer energy to the particles in the ice water, causing the ice to melt.



2. Thermal energy continues to be transferred to the water after all of the ice has melted.

3. Eventually, the juice, bottle, and water have the same temperature. The juice and bottle have become colder, and the water has become warmer.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Quick Lab

Heat Exchange

1. Fill a **film canister** with **hot water.** Insert the **thermometer apparatus** prepared by your teacher. Record the temperature.
2. Fill a **250 mL beaker** two-thirds full with **cool water.** Insert **another thermometer** into the cool water, and record its temperature.
3. Place the canister in the cool water. Record the temperature measured by each thermometer every 30 s.
4. When the thermometers read nearly the same temperature, stop and graph your data. Plot temperature (*y*-axis) versus time (*x*-axis).
5. Describe what happens to the rate of energy transfer as the two temperatures get closer.

thermal conduction the transfer of energy as heat through a material

Conduction, Convection, and Radiation

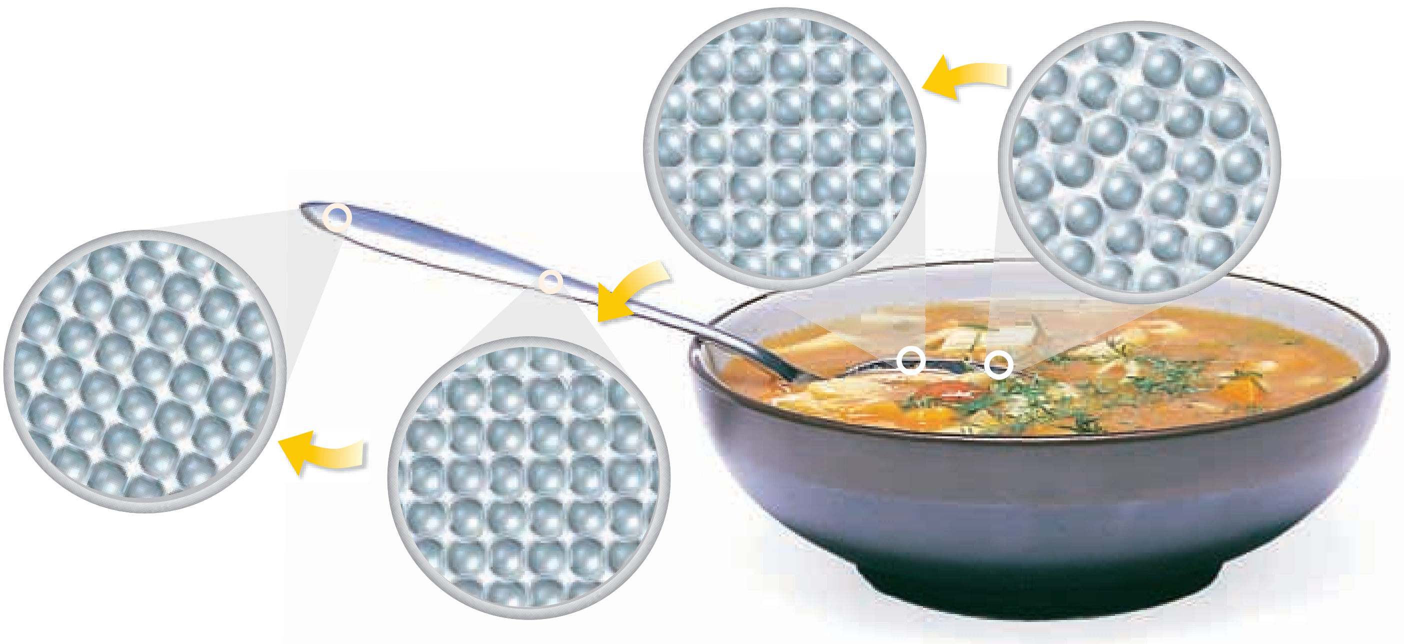
You already know several examples of energy transfer. You know that stoves transfer energy to soup in a pot. You adjust the temperature of your bath water by adding cold or hot water to the tub. And the sun warms your skin. In the next few pages, you'll learn about three ways to transfer thermal energy: *conduction, convection,* and *radiation*.

Conduction

Imagine that you have put a cold metal spoon in a bowl of hot soup, as shown in **Figure 4.** Soon, the handle of the spoon warms up—even though it is not in the soup! The entire spoon gets warm because of conduction. **Thermal conduction** is the transfer of thermal energy from one substance to another through direct contact. Conduction can also occur within a substance, such as the spoon in **Figure 4.**

How does conduction work? When objects touch each other, their particles collide. Thermal energy is transferred from the higher-temperature substance to the lower-temperature substance. Remember that particles of substances at different temperatures have different average kinetic energies. So, when particles collide, particles with higher kinetic energy transfer energy to those with lower kinetic energy. This transfer makes some particles slow down and other particles speed up until all particles have the same average kinetic energy. As a result, the substances have the same temperature.

Figure 4 *The end of this spoon will warm up because conduction, the transfer of energy through direct contact, occurs all the way up the handle.*



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Conductors and Insulators

Substances that conduct thermal energy very well are called **thermal conductors.** For example, the metal in a doctor's stethoscope is a conductor. Energy is transferred rapidly from your warm skin to the cool stethoscope. That's why the stethoscope feels cold. Substances that do not conduct thermal energy very well are called **thermal insulators.** For example, a doctor's wooden tongue depressor is an insulator. It is at the same temperature as the stethoscope. But the tongue depressor doesn't feel cold. The reason is that thermal energy is transferred very slowly from your tongue to the wood. Some typical conductors and insulators are shown in **Table 1** at right.

Reading Check **How can two objects that are the same temperature feel as if they are at different temperatures?**

Table 1 Conductors and Insulators

Conductors	Insulators
Curling iron	Flannel shirt
Cookie sheet	Oven mitt
Iron skillet	Plastic spatula
Copper pipe	Fiberglass insulation
Stove coil	Ceramic bowl

Convection

A second way thermal energy is transferred is **convection,** the transfer of thermal energy by the movement of a liquid or a gas. Look at **Figure 5.** When you boil water in a pot, the water moves in roughly circular patterns because of convection. The water at the bottom of a pot on a stove burner gets hot because it is touching the pot (conduction). As it heats, the water becomes less dense because its higher-energy particles spread apart. The warmer water rises through the denser, cooler water above it. At the surface, the warm water begins to cool. The particles move closer together, making the water denser. The cooler water then sinks back to the bottom. It is heated again, and the cycle begins again. This circular motion of liquids or gases due to density differences that result from temperature differences is called a *convection current.*

thermal conductor a material through which energy can be transferred as heat

thermal insulator a material that reduces or prevents the transfer of heat

convection the transfer of thermal energy by the circulation or movement of a liquid or gas

Figure 5 *The repeated rising and sinking of water during boiling are due to convection.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

radiation the transfer of energy as electromagnetic waves

Radiation

A third way thermal energy is transferred is **radiation,** the transfer of energy by electromagnetic waves, such as visible light and infrared waves. Unlike conduction and convection, radiation can involve either an energy transfer between particles of matter or an energy transfer across empty space.

All objects, including the heater in **Figure 6,** radiate electromagnetic waves. The sun emits visible light, which you can see, and waves of other frequencies, such as infrared and ultraviolet waves, which you cannot see. When your body absorbs infrared waves, you feel warmer.

Figure 6 *The coils of this portable heater warm a room partly by radiating visible light and infrared waves.*

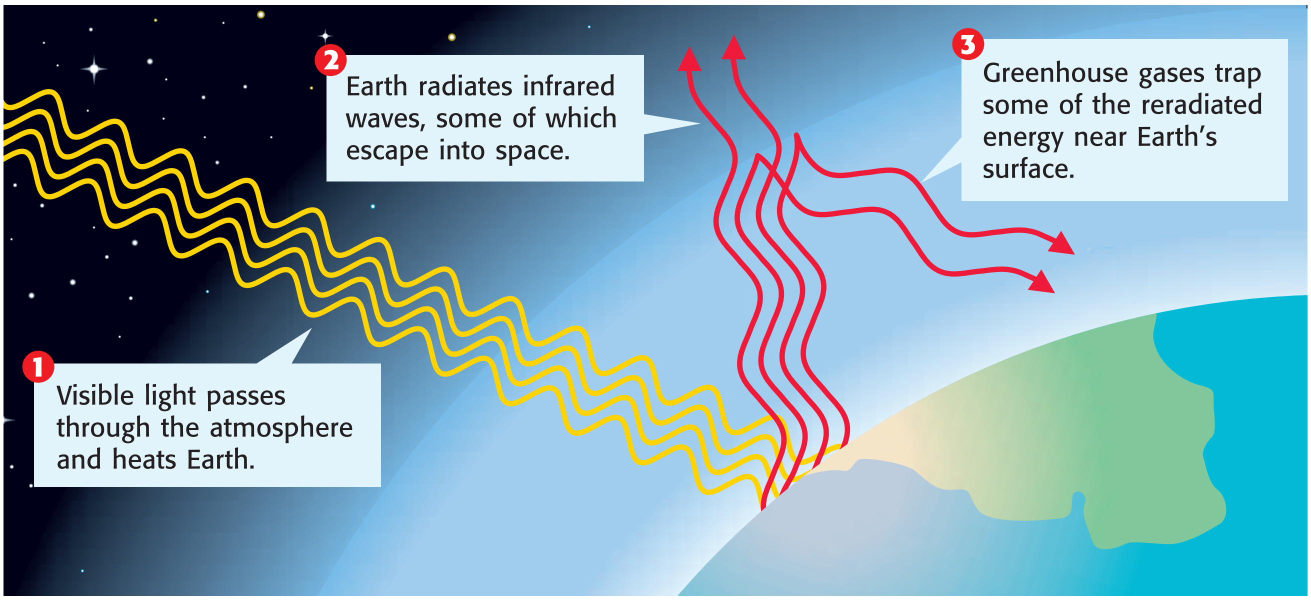
Radiation and the Greenhouse Effect

Earth's atmosphere acts like the windows of a greenhouse. It allows the sun's visible light to pass through it. A greenhouse also traps heat energy, keeping the inside warm. The atmosphere traps some energy, too. This process, called the *greenhouse effect,* is illustrated in **Figure 7.** If our atmosphere did not trap the sun's energy in this way, most of the sun's energy that reached Earth would be radiated immediately back into space. Earth would be a cold, lifeless planet.

The atmosphere traps the sun's energy because of *greenhouse gases,* such as water vapor, carbon dioxide, and methane, which trap energy especially well. Some scientists are concerned that high levels of greenhouse gases in the atmosphere may trap too much energy and make Earth too warm.

Reading Check What is the greenhouse effect?

Figure 7 **The Greenhouse Effect**



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Heat and Temperature Change

On a hot summer day, have you ever fastened your seat belt in a car? If so, you may have noticed that the metal buckle felt hotter than the cloth belt. Why?

Thermal Conductivity

Different substances have different thermal conductivities. *Thermal conductivity* is the rate at which a substance conducts thermal energy. The metal buckle of a seat belt, such as the one shown in **Figure 8,** has a higher thermal conductivity than the cloth belt has. Because of its higher thermal conductivity, the metal transfers energy more rapidly to your hand when you touch it than the cloth does. So, even if the cloth and metal are at the same temperature, the metal feels hotter.

Figure 8 *The cloth part of a seat belt does not feel as hot as the metal part.*

Specific Heat

Another difference between the metal and the cloth is how easily each changes temperature when it absorbs or loses energy. When equal amounts of energy are transferred to or from equal masses of different substances, the change in temperature for each substance will differ. **Specific heat** is the amount of energy needed to change the temperature of 1 kg of a substance by 1°C.

specific heat the quantity of heat required to raise a unit mass of homogeneous material 1 K or 1°C in a specified way given constant pressure and volume

Look at **Table 2.** The specific heat of the cloth of a seat belt is more than twice that of the metal buckle. So, for equal masses of metal and cloth, the same thermal energy will increase the temperature of the metal twice as much as the cloth. The higher the specific heat of something is, the more energy it takes to increase its temperature. **Table 2** shows that most metals have very low specific heats. On the other hand, the specific heat of water is very high. This is why swimming-pool water usually feels cool, even on a hot day. The same energy heats up the air more than it heats up the water.

CONNECTION TO Social Studies

WRITING SKILL **Living near Coastlines** Water has a higher specific heat than land does. Because of water's high specific heat, the ocean has a moderating effect on the weather of coastal areas. The mild weather of coastal areas is one reason they tend to be heavily populated. Find out what the weather is like in various coastal areas in the world. Research the various reasons why coastal areas tend to be heavily populated, and write a brief report in your **science journal.**

Table 2 Specific Heat of Some Common Substances

Substance	Specific heat (J/kg•°C)	Substance	Specific heat (J/kg•°C)
Lead	128	Glass	837
Gold	129	Aluminum	899
Copper	387	Cloth of seat belt	1,340
Iron	448	Ice	2,090
Metal of seat belt	500	Water	4,184

Copyright © by Holt, Rinehart and Winston. All rights reserved.

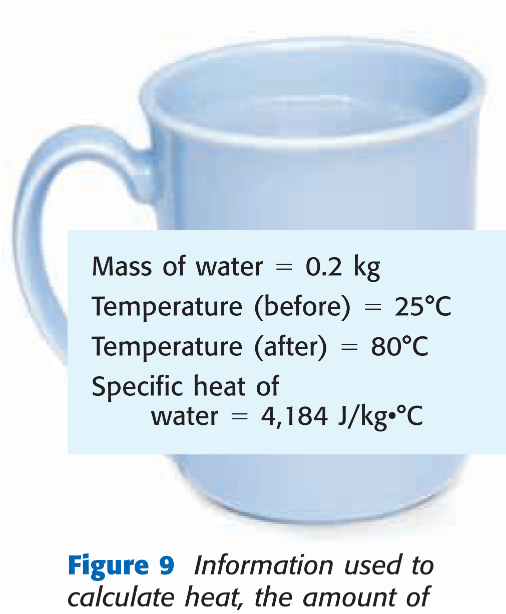


Figure 9 *Information used to calculate heat, the amount of energy transferred to the water, is shown above.*

Heat, Temperature, and Amount

Unlike temperature, energy transferred between objects cannot be measured directly. Instead, it must be calculated. When calculating energy transferred between objects, you can use the definition of *heat* as the amount of energy that is transferred between two objects that are at different temperatures. Heat can then be expressed in joules (J).

How much energy is needed to heat a cup of water to make tea? To answer this question, you have to consider the water's mass, its change in temperature, and its specific heat. These are all listed in **Figure 9.** In general, if you know an object's mass, its change in temperature, and its specific heat, you can use the equation below to calculate heat.

$$\textit{heat}\ (\text{J}) = \textit{specific heat}\ (\text{J/kg}\bullet{}^\circ\text{C}) \times \textit{mass}\ (\text{kg}) \times \textit{change in temperature}\ ({}^\circ\text{C})$$

Calculating Heat

Using the equation above, you can calculate the heat transferred to the water. Because the water's temperature increases, the value of heat is positive. You can also use this equation to calculate the heat transferred from an object when it cools down. The value for heat would then be negative because the temperature decreases.

Reading Check **What are the three pieces of information needed to calculate heat?**

MATH FOCUS

Calculating Heat Calculate the heat transferred to a mass of 0.2 kg of water to change the temperature of the water from 25°C to 80°C. (The specific heat of water is 4,184 J/kg•°C.)

Step 1: Write the equation for calculating heat.

$$\textit{heat} = \textit{specific heat} \times \textit{mass} \times \textit{change in temperature}$$

Step 2: Replace the specific heat, mass, and temperature change with the values given in the problem, and solve.

$$\textit{heat} = 4{,}184\ \text{J/kg}\bullet{}^\circ\text{C} \times 0.2\ \text{kg} \times (80^\circ\text{C} - 25^\circ\text{C})$$

$$\textit{heat} = 46{,}024\ \text{J}$$

Now It's Your Turn

1. Imagine that you heat 2.0 kg of water to make pasta. The temperature of the water before you heat it is 40°C, and the temperature after is 100°C. How much heat was transferred to the water?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION Review

Summary

- Heat is energy transferred between objects that are at different temperatures.
- Thermal energy is the total kinetic energy of the particles that make up a substance.
- Thermal energy will always be transferred from higher to lower temperature.
- Transfer of thermal energy ends when two objects that are in contact are at the same temperature.
- Conduction, convection, and radiation are three ways thermal energy is transferred.
- Specific heat is the amount of energy needed to change the temperature of 1 kg of a substance by 1°C.
- Energy transferred by heat cannot be measured directly. It must be calculated using specific heat, mass, and change in temperature.
- Energy transferred by heat is expressed in joules (J) and is calculated as follows: *heat* (J) = *specific heat* (J/kg•°C) × *mass* (kg) × *change in temperature* (°C).

Using Key Terms

For each pair of terms, explain how the meanings of the terms differ.

1. *thermal conductor* and *thermal insulator*
2. *convection* and *radiation*

Understanding Key Ideas

3. Two objects NOT at thermal equilibrium are in contact. Which of the following happens to their thermal energy?
   a. Their thermal energies remain the same.
   b. Thermal energy passes from the cooler object to the warmer object.
   c. Thermal energy passes from the warmer object to the cooler object.
   d. Thermal energy passes back and forth equally between the two objects.
4. What is heat?

Math Skills

5. The specific heat of lead is 128 J/kg•°C. How much heat is needed to raise the temperature of a 0.015 kg sample of lead by 10°C?

Critical Thinking

6. **Making Inferences** Two objects have the same total thermal energy. They are different sizes. Are they at the same temperature? Explain.
7. **Applying Concepts** Why do many metal cooking utensils have wooden handles?

Interpreting Graphics

8. Look at the photo below. It shows examples of heat transfer by conduction, convection, and radiation. Indicate which type of heat transfer is happening next to each letter.

SCILINKS® NSTA
Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: What Is Heat?
SciLinks code: HSM1661

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Using Scientific Methods

Skills Practice Lab

Feel the Heat

OBJECTIVES

Measure the temperature change when hot and cold objects come into contact.

Compare materials for their ability to hold thermal energy.

MATERIALS

- balance, metric
- cups, plastic-foam, 9 oz (2)
- cylinder, graduated, 100 mL
- nails (10 to 12)
- string, 30 cm length
- paper towels
- rubber band
- thermometer
- water, cold
- water, hot

SAFETY

Heat is the energy transferred between objects at different temperatures. Energy moves from objects at higher temperatures to objects at lower temperatures. If two objects are left in contact for a while, the warmer object will cool down and the cooler object will warm up until they eventually reach the same temperature. In this activity, you will combine equal masses of water and nails at different temperatures to determine which has a greater effect on the final temperature.

Ask a Question

1. When you combine substances at two different temperatures, will the final temperature be closer to the initial temperature of the warmer substance or of the colder substance, or halfway in between?

Form a Hypothesis

2. Write a prediction that answers the question in item 1.

Test the Hypothesis

3. Copy the table below onto a separate sheet of paper.
4. Use the rubber band to bundle the nails together. Find and record the mass of the bundle. Tie a length of string around the bundle, leaving one end of the string 15 cm long.
5. Put the bundle of nails into one of the cups, letting the string dangle outside the cup. Fill the cup with enough hot water to cover the nails, and set it aside for at least 5 min.

Data Collection Table

Trial	Mass of nails (g)	Volume of water that equals mass of nails (mL)	Initial temp. of water and nails (°C)	Initial temp. of water to which nails will be transferred (°C)	Final temp. of water and nails combined (°C)
1					
2					

DO NOT WRITE IN BOOK

Copyright © by Holt, Rinehart and Winston. All rights reserved.

6. Use the graduated cylinder to measure enough cold water to exactly equal the mass of the nails (1 mL of water = 1 g). Record this volume in the table.
7. Measure and record the temperature of the hot water with the nails and the temperature of the cold water.
8. Use the string to transfer the bundle of nails to the cup of cold water. Use the thermometer to monitor the temperature of the water-nail mixture. When the temperature stops changing, record this final temperature in the table.
9. Empty the cups, and dry the nails.
10. For Trial 2, repeat steps 4 through 9, but switch the hot and cold water. Record all of your measurements.

Analyze the Results

1. **Analyzing Results** In Trial 1, you used equal masses of cold water and nails. Did the final temperature support your initial prediction? Explain.
2. **Analyzing Results** In Trial 2, you used equal masses of hot water and nails. Did the final temperature support your initial prediction? Explain.
3. **Explaining Events** In Trial 1, which material—the water or the nails—changed temperature the most after you transferred the nails? What about in Trial 2? Explain your answers.

Draw Conclusions

4. **Drawing Conclusions** The cold water in Trial 1 gained energy. Where did the energy come from?
5. **Evaluating Results** How does the energy gained by the nails in Trial 2 compare with the energy lost by the hot water in Trial 2? Explain.
6. **Applying Conclusions** Which material seems to be able to hold energy better? Explain your answer.
7. **Interpreting Information** Specific heat is a property of matter that indicates how much energy is required to change the temperature of 1 kg of a material by 1°C. Which material in this activity has a higher specific heat (changes temperature less for the same amount of energy)?
8. **Making Predictions** Would it be better to have pots and pans made from a material with a high specific heat or a low specific heat? Explain your answer.

Communicating Your Data

Share your results with your classmates. Discuss how you would change your prediction to include your knowledge of specific heat.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Chapter Review

USING KEY TERMS

1. Use each of the following terms in a separate sentence: *thermal equilibrium*, *convection*, and *radiation*.

For each pair of terms, explain how the meanings of the terms differ.

2. *conduction* and *heat*

3. *conductor* and *insulator*

4. *temperature* and *thermal energy*

UNDERSTANDING KEY IDEAS

Multiple Choice

5. Which of the following temperatures is the lowest?
   - **a.** 100°C
   - **b.** 100°F
   - **c.** 100 K
   - **d.** They are all the same.

6. Which of the following materials would NOT be a good insulator?
   - **a.** wood
   - **b.** cloth
   - **c.** metal
   - **d.** rubber

7. When a spoon at room temperature is placed into a bowl of very hot soup, thermal energy
   - **a.** is transferred from the spoon to the soup.
   - **b.** is transferred from the soup to the spoon.
   - **c.** does not move in either direction.
   - **d.** moves by radiation to the spoon.

8. An item that is probably a good thermal insulator is a
   - **a.** cast-iron skillet.
   - **b.** microwave-safe cooking dish.
   - **c.** car door handle made of stainless steel.
   - **d.** Both (a) and (c)

9. Compared with the Pacific Ocean, a cup of hot chocolate has
   - **a.** more thermal energy and a higher temperature.
   - **b.** less thermal energy and a higher temperature.
   - **c.** more thermal energy and a lower temperature.
   - **d.** less thermal energy and a lower temperature.

Short Answer

10. How does temperature relate to kinetic energy?

11. What are the differences between conduction, convection, and radiation?

12. Explain why bridges may need thermal expansion strips.

Math Skills

13. The weather forecast calls for a temperature of 84°F. What is the corresponding temperature in degrees Celsius? in kelvins?

14. Suppose 1.3 kg of water is heated from 20°C to 100°C. How much energy was transferred to the water? (Water's specific heat is 4,184 J/kg•°C.)

Copyright © by Holt, Rinehart and Winston. All rights reserved.

CRITICAL THINKING

15 **Concept Mapping** Use the following terms to create a concept map: *thermal energy, temperature, radiation, heat, conduction,* and *convection*.

16 **Applying Concepts** The metal lid is stuck on a glass jar of jelly. Explain why running hot water over the lid will help you get the lid off.

17 **Applying Concepts** How does a down jacket keep you warm? (Hint: Think about what insulation does.)

18 **Predicting Consequences** Why do experts recommend that you wear several layers of clothing on a cold day?

19 **Evaluating Assumptions** Someone claims that a large bowl of soup has more thermal energy than a small bowl of soup does. Is this always true? Explain.

20 **Analyzing Processes** In a hot-air balloon, air is heated by a flame. Explain how this enables the balloon to float in the air.

21 **Analyzing Processes** What is different about the two kinds of metal on the bimetallic strip of a thermostat coil?

22 **Making Comparisons** How is radiation different from both conduction and convection?

INTERPRETING GRAPHICS

Use the table below to answer the questions that follow.

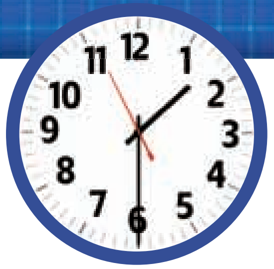
To convert	Use the equation
Celsius to Fahrenheit °C → °F	$°F = \left(\frac{9}{5} \times °C\right) + 32$
Fahrenheit to Celsius °F → °C	$°C = \frac{5}{9} \times (°F - 32)$
Celsius to Kelvin °C → K	$K = °C + 273$
Kelvin to Celsius K → °C	$°C = K - 273$

23 Convert 861 K to degrees Celsius. Show your work.

24 Which is hotter: 572°F or 573 K?

25 Each degree Celsius is equal to how many degrees Fahrenheit?

Copyright © by Holt, Rinehart and Winston. All rights reserved.



Standardized Test Preparation

EOG Prep

READING

Read each of the passages below. Then, answer the questions that follow each passage.

Passage 1 All matter is made up of particles. Temperature is a measure of the average kinetic energy of these particles. The colder a substance gets, the less kinetic energy its particles have, and the slower the particles move. In theory, at absolute zero (–273°C), all movement of particles should stop. Scientists are working in laboratories to cool matter so much that the temperature approaches absolute zero.

1. What is the purpose of this text?
- **A** to entertain
- **B** to influence
- **C** to express
- **D** to inform

2. What does information in the passage suggest?
- **F** Matter at absolute zero no longer exists.
- **G** No one knows what would happen to matter at absolute zero.
- **H** It is currently not possible to cool matter to absolute zero.
- **I** Scientists have cooled matter to absolute zero.

3. What information does the passage give about the relationship between kinetic energy and temperature?
- **A** The higher the temperature, the more kinetic energy a substance has.
- **B** There is no relationship between temperature and kinetic energy.
- **C** The higher the temperature, the less kinetic energy a substance has.
- **D** No one knows what the relationship between kinetic energy and temperature is.

Passage 2 Birds and mammals burn fuel to maintain body temperatures that are usually greater than the air temperature of their surroundings. A lot of energy is necessary to maintain a high body temperature. Tiny animals such as shrews and hummingbirds maintain high body temperatures only during the day. At night or when the air temperature falls significantly, these tiny creatures go into a state called torpor. When an animal is in torpor, its respiration and heart rate are slow. Circulation continues primarily to major organs. Body temperature drops. Because their body processes are slowed, animals in torpor use much less energy than they usually need.

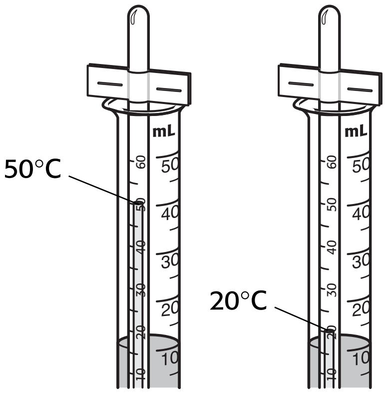
1. Which of the following would be the **best** summary of this passage?
- **A** Some animals use less energy than other animals.
- **B** Some animals use more energy than other animals.
- **C** Some animals maintain high body temperatures only during the day, going into torpor at night.
- **D** Going into torpor at night is necessary for some animals to maintain high body temperatures.

2. What happens when an animal goes into torpor?
- **F** Respiration and heart rate slow, and body temperature drops.
- **G** Normal respiration and heart rate are maintained, and body temperature drops.
- **H** Respiration and heart rate increase, and body temperature drops.
- **I** Respiration and heart rate increase, and body temperature rises.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

INTERPRETING GRAPHICS

The figure below shows a thermometer in each of two graduated cylinders holding water. Use the figure below to answer the questions that follow.



1. Which graduated cylinder contains more water?
   A The cylinder on the left contains more.
   B The cylinder on the right contains more.
   C The cylinders contain equal amounts.
   D There is not enough information to determine the answer.

2. If the two cylinders are touching each other, what will happen to the thermal energy in the cylinders?
   F It will pass from the left cylinder to the right cylinder.
   G It will pass from the right cylinder to the left cylinder.
   H It will pass equally between the two cylinders.
   I Nothing will happen.

3. If the water in the graduated cylinders is mixed together, which of the following will most likely be the temperature of the mixture?
   A 25°C
   B 35°C
   C 50°C
   D 70°C

MATH

Read each question below, and choose the best answer.

1. Elena has a bag containing 4 blue marbles, 6 red marbles, and 3 green marbles. She picks 1 marble at random. What is the probability of her picking a blue marble?
   A 1 in 13
   B 1 in 4
   C 4 in 13
   D 9 in 13

2. If $8 - 2n = -30$, what is the value of n?
   F 7
   G 19
   H 68
   I 120

3. A rectangle has sides of 4 cm and 10 cm. If the lengths of each of its sides are reduced by half, what will the change in the area of the rectangle be?
   A 1/4 as much area
   B 1/2 as much area
   C 2 times as much area
   D 4 times as much area

4. The specific heat of copper is 387 J/kg•°C. If the temperature of 0.05 kg of copper is raised from 25°C to 30°C, how much heat was put into the copper?
   F 96.8 J
   G 484 J
   H 581 J
   I 96,800 J

5. A change in temperature of 1°C is equal to a change in temperature of 1 K. The temperature 0°C is equal to the temperature 273 K. If the temperature is 300 K, what is the temperature in degrees Celsius?
   A –27°C
   B 27°C
   C 54°C
   D 73°C

Standardized Test Preparation

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Science in Action

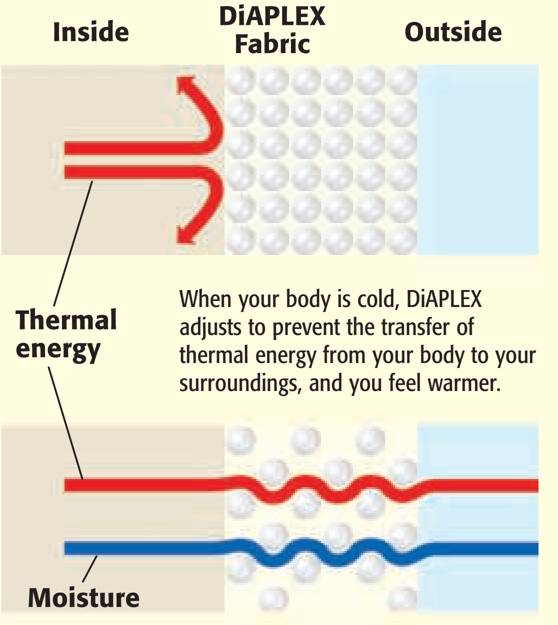
Scientific Discoveries

The Deep Freeze

All matter is made up of tiny, constantly vibrating particles. Temperature is a measure of the average kinetic energy of particles. The colder a substance gets, the slower its particles move. Scientists are interested in how matter behaves when it is cooled to almost absolute zero, the absence of all thermal energy, which is about –273°C. In one method, scientists aim lasers at gas particles, holding them so still that their temperature is less than one-millionth of a degree from absolute zero. It's like turning on several garden hoses and pointing each from a different angle at a soccer ball so that the ball won't move in any direction.

Math ACTIVITY

Think of the coldest weather you have ever been in. What was the temperature? Convert this temperature to kelvins. Compare this temperature with absolute zero.



When your body is cold, DiAPLEX adjusts to prevent the transfer of thermal energy from your body to your surroundings, and you feel warmer.

When your body gets too warm, DiAPLEX adjusts to allow your body to transfer excess thermal energy and moisture to your surroundings, and you feel cooler.

Science, Technology, and Society

DiAPLEX®: The Intelligent Fabric

Wouldn't it be great if you had a winter coat that could automatically adjust to keep you cozy regardless of the outside temperature? Well, scientists have developed a new fabric called DiAPLEX that can be used to make such a coat!

Like most winter coats, DiAPLEX is made from nylon. But whereas most nylon fabrics have thousands of tiny pores, or openings, DiAPLEX doesn't have pores. It is a solid film. This film makes DiAPLEX even more waterproof than other nylon fabrics.

Language Arts ACTIVITY

WRITING SKILL Think of two different items of clothing that you wear when the weather is cool or cold. Write a paragraph explaining how you think each of them works in keeping you warm when it is cold outside. Does one keep you warmer than the other? How does it do so?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Michael Reynolds

Earthship Architect Would you want to live in a house without a heating system? You could if you lived in an Earthship! Earthships are the brainchild of Michael Reynolds, an architect in Taos, New Mexico. These houses are designed to make the most of our planet's most abundant source of energy, the sun.

Each Earthship takes full advantage of passive solar heating. For example, large windows face south in order to maximize the amount of energy the house receives from the sun. Each home is partially buried in the ground. The soil helps keep the energy that comes in through the windows inside the house.

To absorb the sun's energy, the outer walls of Earthships are massive and thick. The walls may be made with crushed aluminum cans or stacks of old automobile tires filled with dirt. These materials absorb the sun's energy and naturally heat the house. Because an Earthship maintains a temperature around 15°C (about 60°F), it can keep its occupants comfortable through all but the coldest winter nights.

Social Studies ACTIVITY

Find out more about Michael Reynolds and other architects who have invented unique ways of building houses that are energy-efficient. Present your findings.

go.hrw.com

To learn more about these Science in Action topics, visit **go.hrw.com** and type in the keyword **HP5HOTF.**

Current Science

Check out Current Science® articles related to this chapter by visiting go.hrw.com. Just type in the keyword HP5CS10.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

TIMELINE

Waves, Sound, and Light

When you hear the word *waves*, you probably think of waves in the ocean. But waves that you encounter every day have a much bigger effect on your life than do water waves! In this unit, you will learn about different types of waves, how waves behave and interact, and how sound energy and light energy travel in waves. This time-line shows some events and discoveries that have occurred throughout history as scientists have sought to learn more about the energy of waves.

Around 1600

Italian astronomer and physicist Galileo Galilei attempts to calculate the speed of light by using lanterns and shutters. He writes that the speed is "extraordinarily rapid."

1903

The popularity of an early movie called *The Great Train Robbery* leads to the establishment of permanent movie theaters.

1960

The first working laser is demonstrated.

1971

Hungarian physicist Dennis Gabor wins the Nobel Prize in physics for his invention of holography, the method used to make holograms.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

1704

Sir Isaac Newton publishes his book *Optiks*, which contains his theories about light and color.

1711

English trumpeter John Shore invents the tuning fork, an instrument that produces a single-frequency note.

1801

British scientist Thomas Young is the first to provide experimental data showing that light behaves as a wave.

1905

Physicist Albert Einstein suggests that light sometimes behaves as a particle.

1929

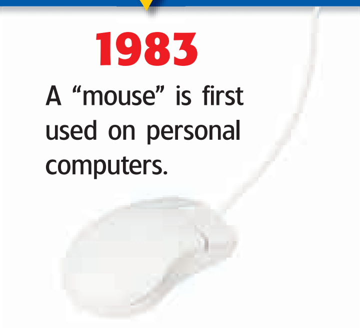
American astronomer Edwin Hubble uses the Doppler effect of light to determine that the universe is expanding.

1947

Anne Frank's *The Diary of a Young Girl* is published. The book is an edited version of the diary kept by a Jewish teenager while in hiding during World War II.

1983

A "mouse" is first used on personal computers.



1997

British pilot Andy Green drives a jet-powered car at 341 m/s, when he becomes the first person to travel faster than the speed of sound on land.

2002

Scientists develop a thermoacoustic refrigerator. The device is cooled using high amplitude sound instead of chemical refrigerants.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

15

The Energy of Waves

About the PHOTO

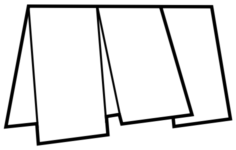
A surfer takes advantage of a wave's energy to catch an exciting ride. The ocean wave that this surfer is riding is just one type of wave. You are probably familiar with water waves. But did you know that light, sound, and even earthquakes are waves? From music to television, waves play an important role in your life every day.

PRE-READING ACTIVITY

FOLDNOTES

Three-Panel Flip Chart

Before you read the chapter, create the FoldNote entitled "Three-Panel Flip Chart" described in the **Study Skills** section of the Appendix. Label the flaps of the three-panel flip chart with "The nature of waves," "Properties of waves," and "Wave interactions." As you read the chapter, write information you learn about each category under the appropriate flap.



Copyright © by Holt, Rinehart and Winston. All rights reserved.

START-UP ACTIVITY

Energetic Waves

In this activity, you will observe the movement of a wave. Then, you will determine the source of the wave's energy.

Procedure

1. Tie one end of a **piece of rope** to the back of a **chair.**
2. Hold the other end in one hand, and stand away from the chair so that the rope is almost straight but is not pulled tight.
3. Move the rope up and down quickly to create a wave. Repeat this step several times. Record your observations.

Analysis

1. In which direction does the wave move?
2. How does the movement of the rope compare with the movement of the wave?
3. Where does the energy of the wave come from?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 1

The Nature of Waves

READING WARM-UP

Objectives

- Describe how waves transfer energy without transferring matter.
- Distinguish between waves that require a medium and waves that do not.
- Explain the difference between transverse and longitudinal waves.

Terms to Learn

wave	transverse wave
medium	longitudinal wave

READING STRATEGY

Discussion Read this section silently. Write down questions that you have about this section. Discuss your questions in a small group.

Imagine that your family has just returned home from a day at the beach. You had fun playing in the ocean under a hot sun. You put some cold pizza in the microwave for dinner, and you turn on the radio. Just then, the phone rings. It's your friend calling to ask about homework.

In the events described above, how many different waves were present? Believe it or not, there were at least five! Can you name them? Here's a hint: A **wave** is any disturbance that transmits energy through matter or empty space. Okay, here are the answers: water waves in the ocean; light waves from the sun; microwaves inside the microwave oven; radio waves transmitted to the radio; and sound waves from the radio, telephone, and voices. Don't worry if you didn't get very many. You will be able to name them all after you read this section.

Reading Check **What do all waves have in common?** (*See the Appendix for answers to Reading Checks.*)

wave a periodic disturbance in a solid, liquid, or gas as energy is transmitted through a medium

Wave Energy

Energy can be carried away from its source by a wave. You can observe an example of a wave if you drop a rock in a pond. Waves from the rock's splash carry energy away from the splash. However, the material through which the wave travels does not move with the energy. Look at **Figure 1.** Can you move a leaf on a pond if you are standing on the shore? You can make the leaf bob up and down by making waves that carry enough energy through the water. But you would not make the leaf move in the same direction as the wave.

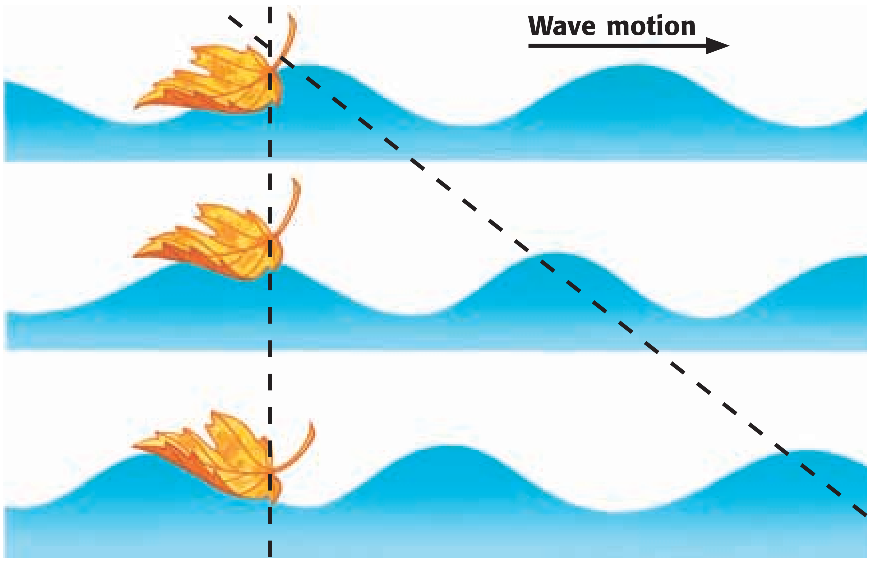


Figure 1 *Waves on a pond move toward the shore, but the water and the leaf floating on the surface only bob up and down.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Waves and Work

As a wave travels, it does work on everything in its path. The waves in a pond do work on the water to make it move up and down. The waves also do work on anything floating on the water's surface. For example, boats and ducks bob up and down with waves. The fact that these objects move tells you that the waves are transferring energy.

Energy Transfer Through a Medium

Most waves transfer energy by the vibration of particles in a medium. A **medium** is a substance through which a wave can travel. A medium can be a solid, a liquid, or a gas. The plural of *medium* is *media*.

When a particle vibrates (moves back and forth, as in **Figure 2**), it can pass its energy to a particle next to it. The second particle will vibrate like the first particle does. In this way, energy is transmitted through a medium.

Sound waves need a medium. Sound energy travels by the vibration of particles in liquids, solids, and gases. If there are no particles to vibrate, no sound is possible. If you put an alarm clock inside a jar and remove all the air from the jar to create a vacuum, you will not be able to hear the alarm.

Other waves that need a medium include ocean waves, which move through water, and waves that are carried on guitar and cello strings when they vibrate. Waves that need a medium are called *mechanical waves*. **Figure 3** shows the effect of a mechanical wave in Earth's crust: an earthquake.

Figure 2 *A vibration is one complete back-and-forth motion of an object.*

medium a physical environment in which phenomena occur

Figure 3 *Earthquakes cause seismic waves to travel through Earth's crust. The energy they carry can be very destructive to anything on the ground.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 4 *Light waves are electromagnetic waves, which do not need a medium. Light waves from the Crab nebula, shown here, travel through the vacuum of space billions of miles to Earth, where they can be detected with a telescope.*

Energy Transfer Without a Medium

Some waves can transfer energy without going through a medium. Visible light is one example. Other examples include microwaves made by microwave ovens, TV and radio signals, and X rays used by dentists and doctors. These waves are *electromagnetic waves*.

Although electromagnetic waves do not need a medium, they can go through matter, such as air, water, and glass. The energy that reaches Earth from the sun comes through electromagnetic waves, which go through space. As shown in **Figure 4,** you can see light from stars because electromagnetic waves travel through space to Earth. Light is an electromagnetic wave that your eyes can see.

✓ *Reading Check* **How do electromagnetic waves differ from mechanical waves?**

CONNECTION TO Astronomy

Light Speed Light waves from stars and galaxies travel great distances that are best expressed in light-years. A light-year is the distance a ray of light can travel in one year. Some of the light waves from these stars have traveled billions of light-years before reaching Earth. Do the following calculation in your **science journal:** If light travels at a speed of 300,000,000 m/s, what distance is a light-minute? (Hint: There are 60 s in a minute.) **ACTIVITY**

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Types of Waves

All waves transfer energy by repeated vibrations. However, waves can differ in many ways. Waves can be classified based on the direction in which the particles of the medium vibrate compared with the direction in which the waves move. The two main types of waves are *transverse waves* and *longitudinal* (LAHN juh TOOD'n uhl) *waves.* Sometimes, a transverse wave and a longitudinal wave can combine to form another kind of wave called a *surface wave.*

INTERNET ACTIVITY

For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HP5WAVW.**

Transverse Waves

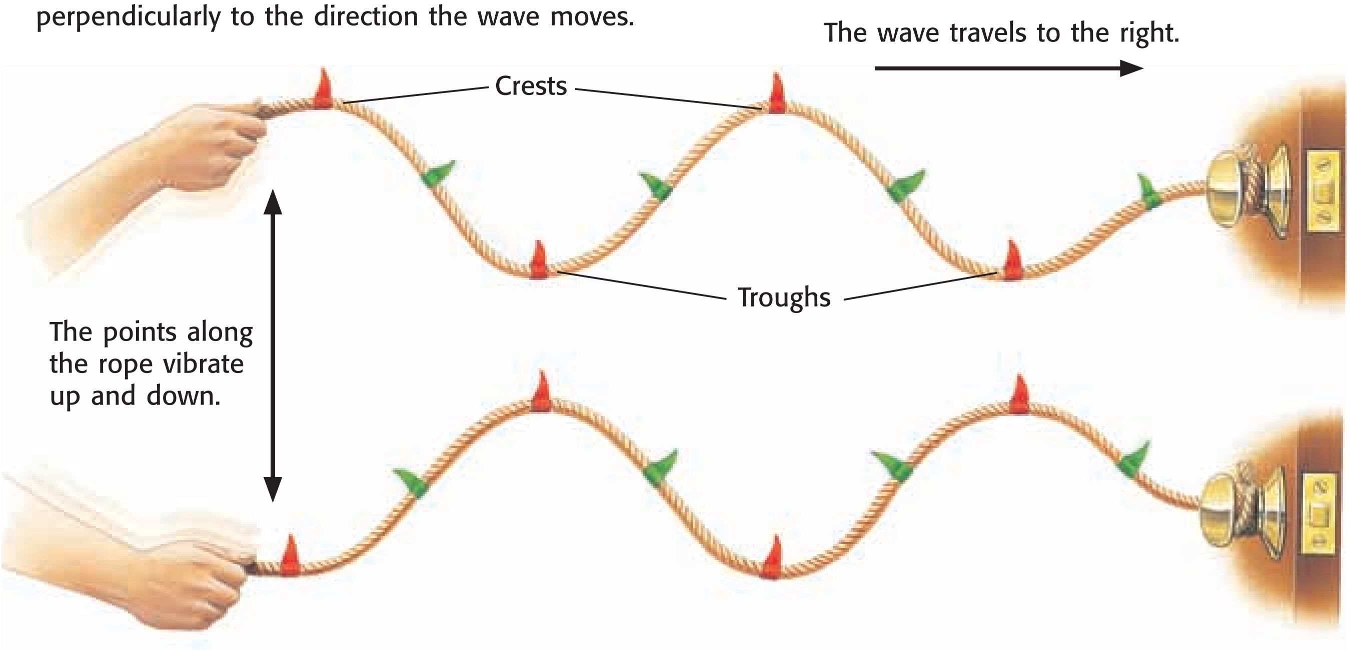
Waves in which the particles vibrate in an up-and-down motion are called **transverse waves.** *Transverse* means "moving across." The particles in this kind of wave move across, or perpendicularly to, the direction that the wave is going. To be *perpendicular* means to be "at right angles."

transverse wave a wave in which the particles of the medium move perpendicularly to the direction the wave is traveling

A wave moving on a rope is an example of a transverse wave. In **Figure 5,** you can see that the points along the rope vibrate perpendicularly to the direction the wave is going. The highest point of a transverse wave is called a *crest,* and the lowest point between each crest is called a *trough* (TRAWF). Although electromagnetic waves do not travel by vibrating particles in a medium, all electromagnetic waves are considered transverse waves. The reason is that the waves are made of vibrations that are perpendicular to the direction of motion.

Figure 5 **Motion of a Transverse Wave**

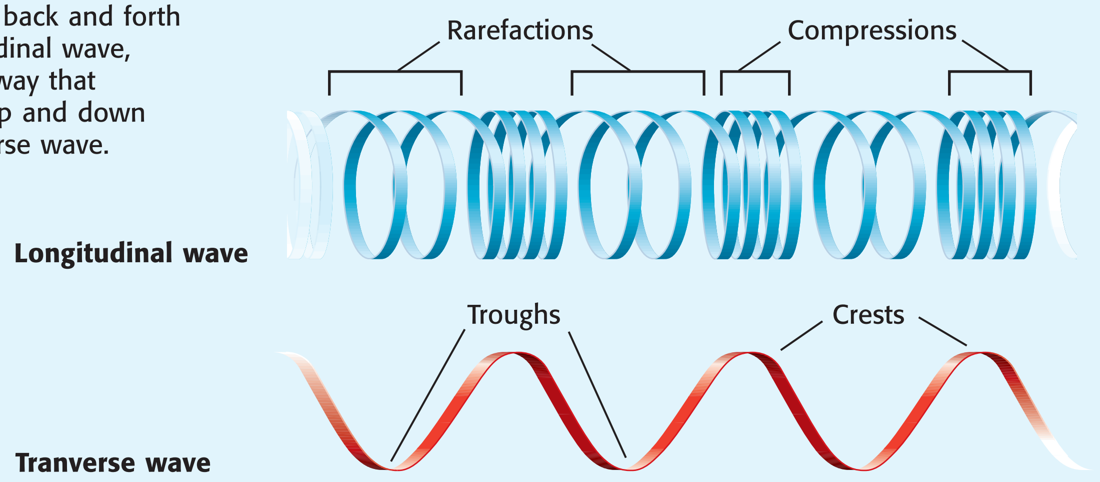
A wave on a rope is a transverse wave because the particles of the medium vibrate perpendicularly to the direction the wave moves.



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 6 **Comparing Longitudinal and Transverse Waves**

Pushing a spring back and forth creates a longitudinal wave, much the same way that shaking a rope up and down creates a transverse wave.



Longitudinal Waves

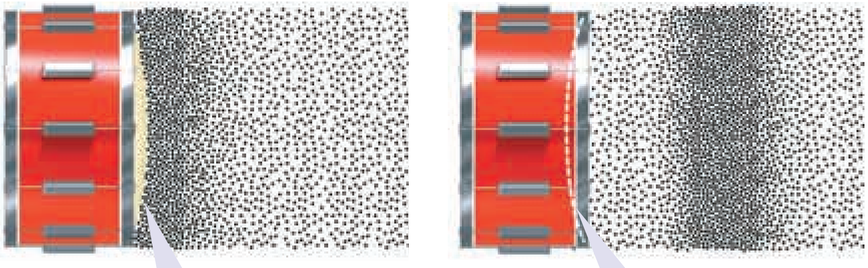
longitudinal wave a wave in which the particles of the medium vibrate parallel to the direction of wave motion

In a **longitudinal wave,** the particles of the medium vibrate back and forth along the path that the wave moves. You can make a longitudinal wave on a spring. When you push on the end of the spring, the coils of the spring crowd together. A part of a longitudinal wave where the particles are crowded together is called a *compression*. When you pull back on the end of the spring, the coils are pulled apart. A part where the particles are spread apart is a *rarefaction* (RER uh FAK shuhn). Compressions and rarefactions are like the crests and troughs of a transverse wave, as shown in **Figure 6.**

Sound Waves

A sound wave is an example of a longitudinal wave. Sound waves travel by compressions and rarefactions of air particles. **Figure 7** shows how a vibrating drum forms compressions and rarefactions in the air around it.

Reading Check **What kind of wave is a sound wave?**



When the drumhead moves out after being hit, a compression is created in the air particles.

When the drumhead moves back in, a rarefaction is created.

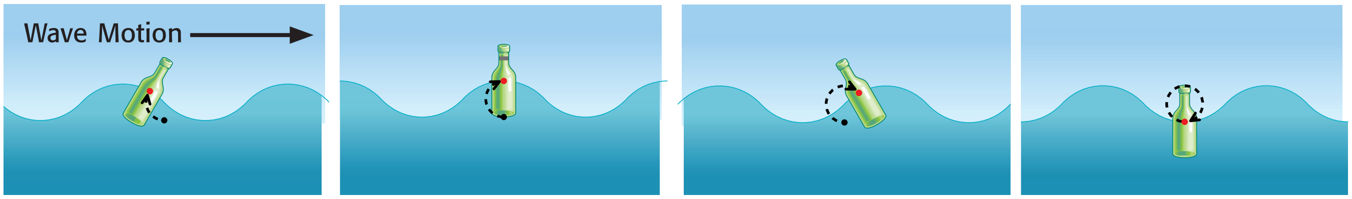
Figure 7 *Sound energy is carried away from a drum by a longitudinal wave through the air.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Combinations of Waves

When waves form at or near the boundary between two media, a transverse wave and a longitudinal wave can combine to form a *surface wave*. An example is shown in **Figure 8.** Surface waves look like transverse waves, but the particles of the medium in a surface wave move in circles rather than up and down. The particles move forward at the crest of each wave and move backward at the trough.

Figure 8 *Ocean waves are surface waves. A floating bottle shows the circular motion of particles in a surface wave.*



SECTION Review

Summary

- A wave is a disturbance that transmits energy.
- The particles of a medium do not travel with the wave.
- Mechanical waves require a medium, but electromagnetic waves do not.
- Particles in a transverse wave vibrate perpendicularly to the direction the wave travels.
- Particles in a longitudinal wave vibrate parallel to the direction that the wave travels.

Using Key Terms

Complete each of the following sentences by choosing the correct term from the word bank.

transverse wave	wave
longitudinal wave	medium

1. In a ___, the particles vibrate parallel to the direction that the wave travels.

2. Mechanical waves require a ___ through which to travel.

3. Any ___ transmits energy through vibrations.

4. In a ___, the particles vibrate perpendicularly to the direction that the wave travels.

Understanding Key Ideas

5. Waves transfer

a. matter. **c.** particles.
b. energy. **d.** water.

6. Name a kind of wave that does not require a medium.

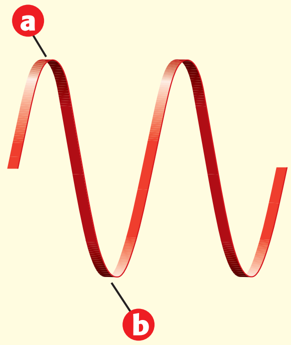
Critical Thinking

7. **Applying Concepts** Sometimes, people at a sports event do "the wave." Is this a real example of a wave? Why or why not?

8. **Making Inferences** Why can supernova explosions in space be seen but not heard on Earth?

Interpreting Graphics

9. Look at the figure below. Which part of the wave is the crest? Which part of the wave is the trough?



SCILINKS® NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: The Nature of Waves; Types of Waves

SciLinks code: HSM1017; HSM1574

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 2

Properties of Waves

You are in a swimming pool, floating on your air mattress, enjoying a gentle breeze. Your friend does a "cannonball" from the high dive nearby. Suddenly, your mattress is rocking wildly on the waves generated by the huge splash.

READING WARM-UP

Objectives

- Identify and describe four wave properties.
- Explain how frequency and wavelength are related to the speed of a wave.

Terms to Learn

amplitude
frequency
wavelength
wave speed

READING STRATEGY

Mnemonics As you read this section, create a mnemonic device to help you remember the wave equation.

The breeze generates waves in the water as well, but they are very different from the waves created by your diving friend. The waves made by the breeze are shallow and close together, while the waves from your friend's splash are tall and widely spaced. Properties of waves, such as the height of the waves and the distance between crests, are useful for comparing and describing waves.

Amplitude

If you tie one end of a rope to the back of a chair, you can create waves by moving the free end up and down. If you shake the rope a little, you will make a shallow wave. If you shake the rope hard, you will make a tall wave.

The **amplitude** of a wave is related to its height. A wave's amplitude is the maximum distance that the particles of a medium vibrate from their rest position. The rest position is the point where the particles of a medium stay when there are no disturbances. The larger the amplitude is, the taller the wave is. **Figure 1** shows how the amplitude of a transverse wave may be measured.

amplitude the maximum distance that the particles of a wave's medium vibrate from their rest position

Larger Amplitude—More Energy

When using a rope to make waves, you have to work harder to create a wave with a large amplitude than to create one with a small amplitude. The reason is that it takes more energy to move the rope farther from its rest position. Therefore, a wave with a large amplitude carries more energy than a wave with a small amplitude does.

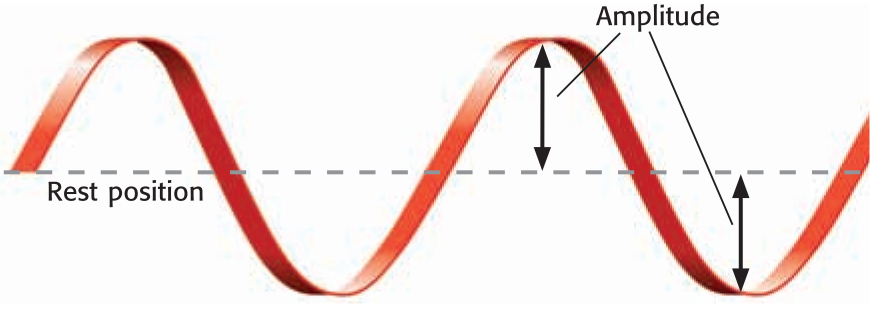


Figure 1 *The amplitude of a transverse wave is measured from the rest position to the crest or to the trough of the wave.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Wavelength

Another property of waves is wavelength. A **wavelength** is the distance between any two crests or compressions next to each other in a wave. The distance between two troughs or rarefactions next to each other is also a wavelength. In fact, the wavelength can be measured from any point on a wave to the next corresponding point on the wave. Wavelength is measured the same way in both a longitudinal wave and a transverse wave, as shown in **Figure 2.**

wavelength the distance from any point on a wave to an identical point on the next wave

Shorter Wavelength—More Energy

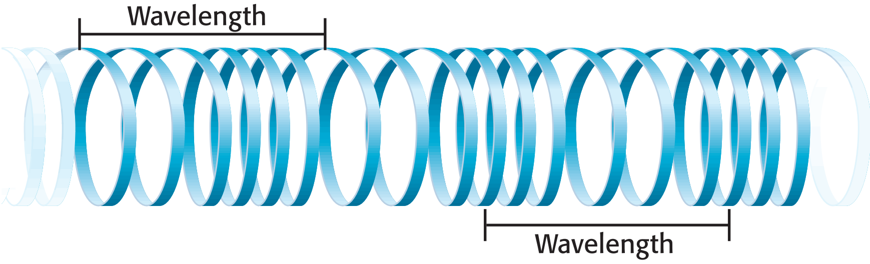
If you are making waves on either a spring or a rope, the rate at which you shake it will determine whether the wavelength is short or long. If you shake it rapidly back and forth, the wavelength will be shorter. If you are shaking it rapidly, you are putting more energy into it than if you were shaking it more slowly. So, a wave with a shorter wavelength carries more energy than a wave with a longer wavelength does.

Reading Check **How does shaking a rope at different rates affect the wavelength of the wave that moves through the rope?** (*See the Appendix for answers to Reading Checks.*)

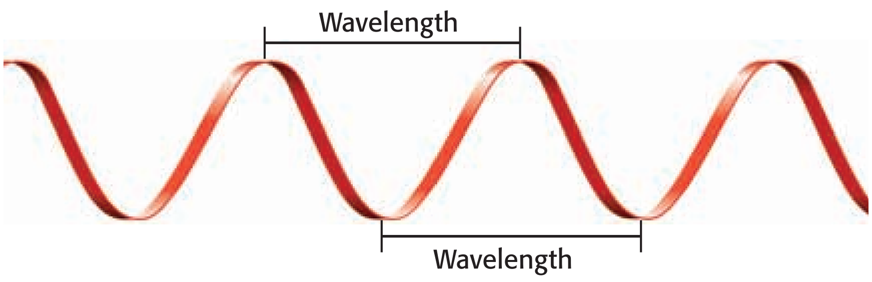
Figure 2 Measuring Wavelengths

Wavelength can be measured from any two corresponding points that are adjacent on a wave.

Longitudinal wave



Transverse wave



Quick Lab

Springy Waves

1. Hold a coiled **spring toy** on the floor between you and a classmate so that the spring is straight. This is the rest position.
2. Move one end of the spring back and forth at a constant rate. Note the wavelength of the wave you create.
3. Increase the amplitude of the waves. What did you have to do? How did the change in amplitude affect the wavelength?
4. Now, shake the spring back and forth about twice as fast as you did before. What happens to the wavelength? Record your observations.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

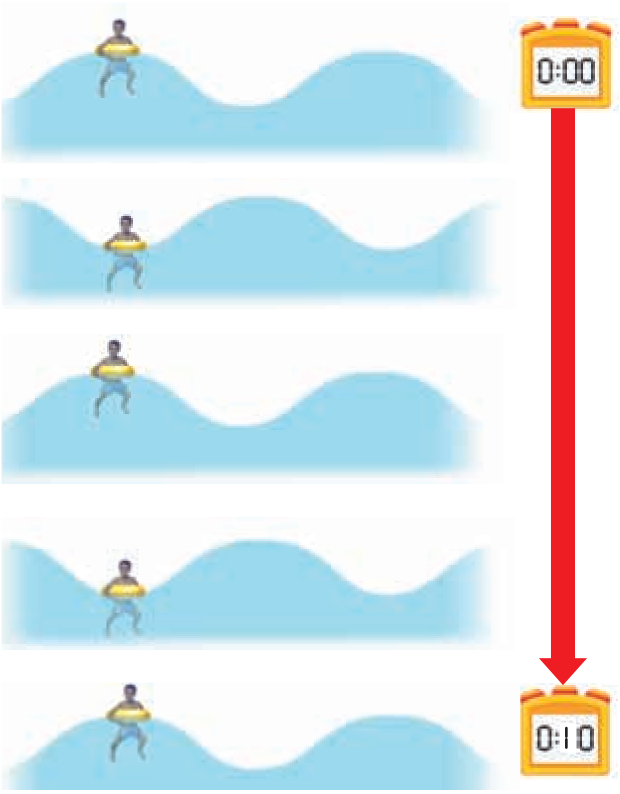


Figure 3 *Frequency can be measured by counting how many waves pass by in a certain amount of time. Here, two waves went by in 10 s, so the frequency is 2/10 s = 0.2 Hz.*

Frequency

Think about making rope waves again. The number of waves that you can make in 1 s depends on how quickly you move the rope. If you move the rope slowly, you make only a small number of waves each second. If you move it quickly, you make a large number of waves. The number of waves produced in a given amount of time is the **frequency** of the wave. Frequency is usually expressed in *hertz* (Hz). For waves, one hertz equals one wave per second (1 Hz = 1/s). **Figure 3** shows a wave with a frequency of 0.2 Hz.

Reading Check **If you make three rope waves per second, what is the frequency of the wave?**

Higher Frequency—More Energy

To make high-frequency waves in a rope, you must shake the rope quickly back and forth. To shake a rope quickly takes more energy than to shake it slowly. Therefore, if the amplitudes are equal, high-frequency waves carry more energy than low-frequency waves.

Wave Speed

Wave speed is the speed at which a wave travels. Wave speed (v) can be calculated using wavelength (λ, the Greek letter *lambda*) and frequency (f), by using the *wave equation*, which is shown below:

$$v = \lambda \times f$$

MATH FOCUS

Wave Calculations Determine the wave speed of a wave that has a wavelength of 5 m and a frequency of 4 Hz.

Step 1: Write the equation for wave speed.

$$v = \lambda \times f$$

Step 2: Replace the λ and f with the values given in the problem, and solve.

$$v = 5 \text{ m} \times 4 \text{ Hz} = 20 \text{ m/s}$$

The equation for wave speed can also be rearranged to determine wavelength or frequency, as shown at top right.

$\lambda = \frac{v}{f}$ (Rearranged by dividing by f.)

$f = \frac{v}{\lambda}$ (Rearranged by dividing by λ.)

Now It's Your Turn

1. What is the frequency of a wave if the wave has a speed of 12 cm/s and a wavelength of 3 cm?
2. A wave has a frequency of 5 Hz and a wave speed of 18 m/s. What is its wavelength?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Frequency and Wavelength Relationship

Three of the basic properties of a wave are related to one another in the wave equation—wave speed, frequency, and wavelength. If you know any two of these properties of a wave, you can use the wave equation to find the third.

One of the things the wave equation tells you is the relationship between frequency and wavelength. If a wave is traveling a certain speed and you double its frequency, its wavelength will be cut in half. Or if you were to cut its frequency in half, the wavelength would be double what it was before. So, you can say that frequency and wavelength are *inversely* related. Think of a sound wave, traveling underwater at 1,440 m/s, given off by the sonar of a submarine like the one shown in **Figure 4.** If the sound wave has a frequency of 360 Hz, it will have a wavelength of 4.0 m. If the sound wave has twice that frequency, the wavelength will be 2.0 m, half as big.

The wave speed of a wave in a certain medium is the same no matter what the wavelength is. So, the wavelength and frequency of a wave depend on the wave speed, not the other way around.

Figure 4 *Submarines use sonar, sound waves in water, to locate underwater objects.*

frequency the number of waves produced in a given amount of time

wave speed the speed at which a wave travels through a medium

SECTION Review

Summary

- Amplitude is the maximum distance the particles of a medium vibrate from their rest position.
- Wavelength is the distance between two adjacent corresponding parts of a wave.
- Frequency is the number of waves that pass a given point in a given amount of time.
- Wave speed can be calculated by multiplying the wave's wavelength by the frequency.

Using Key Terms

1. In your own words, write a definition for each of the following terms: *amplitude, frequency,* and *wavelength*.

Understanding Key Ideas

2. Which of the following results in more energy in a wave?
   a. a smaller wavelength
   b. a lower frequency
   c. a shallower amplitude
   d. a lower speed
3. Draw a transverse wave, and label how the amplitude and wavelength are measured.

Math Skills

4. What is the speed (v) of a wave that has a wavelength (λ) of 2 m and a frequency (f) of 6 Hz?

Critical Thinking

5. **Making Inferences** A wave has a low speed but a high frequency. What can you infer about its wavelength?
6. **Analyzing Processes** Two friends blow two whistles at the same time. The first whistle makes a sound whose frequency is twice that of the sound made by the other whistle. Which sound will reach you first?

SCILINKS NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Properties of Waves
SciLinks code: HSM1236

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 3

Wave Interactions

If you've ever seen a planet in the night sky, you may have had a hard time telling it apart from a star. Both planets and stars shine brightly, but the light waves that you see are from very different sources.

READING WARM-UP

Objectives

- Describe reflection, refraction, diffraction, and interference.
- Compare destructive interference with constructive interference.
- Describe resonance, and give examples.

Terms to Learn

reflection	interference
refraction	standing wave
diffraction	resonance

READING STRATEGY

Reading Organizer As you read this section, make a concept map by using the terms above.

All stars, including the sun, produce light. But planets do not produce light. So, why do planets shine so brightly? The planets and the moon shine because light from the sun *reflects* off them. Without reflection, you would not be able to see the planets. Reflection is one of the wave interactions that you will learn about in this section.

Reflection

Reflection happens when a wave bounces back after hitting a barrier. All waves—including water, sound, and light waves—can be reflected. The reflection of water waves is shown in **Figure 1.** Light waves reflecting off an object allow you to see that object. For example, light waves from the sun are reflected when they strike the surface of the moon. These reflected waves allow us to enjoy moonlit nights. A reflected sound wave is called an *echo*.

Waves are not always reflected when they hit a barrier. If all light waves were reflected when they hit your eyeglasses, you would not be able to see anything! A wave is *transmitted* through a substance when it passes through the substance.

reflection the bouncing back of a ray of light, sound, or heat when the ray hits a surface that it does not go through

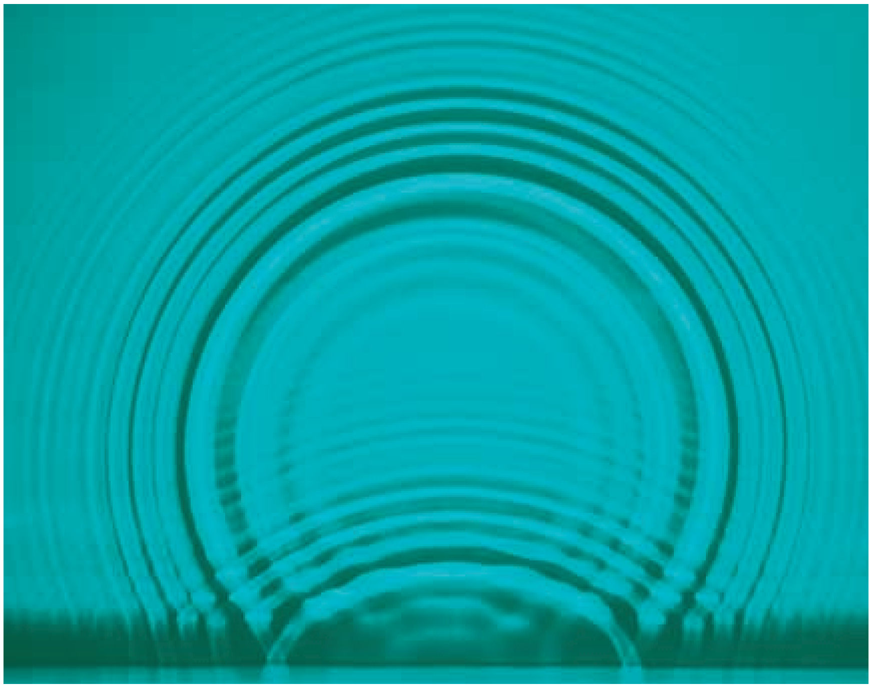


Figure 1 *These water waves are reflecting off the side of the container.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

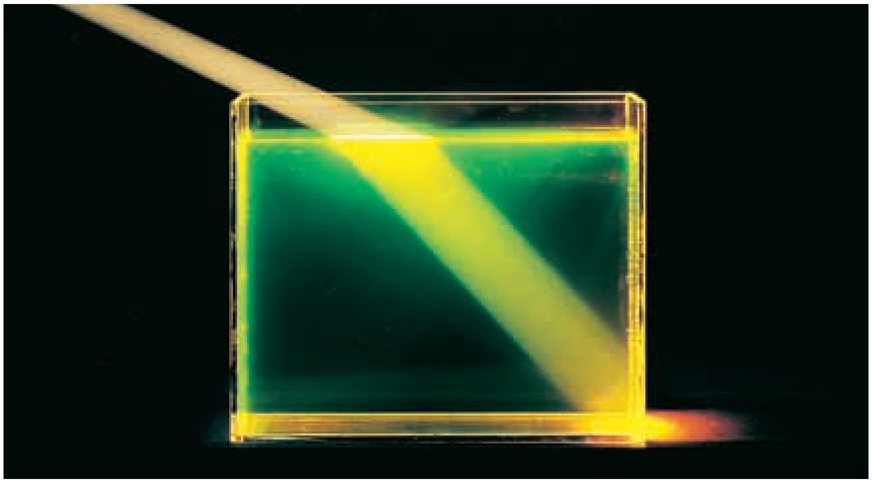


Figure 2 *A light wave passing at an angle into a new medium—such as water—is refracted because the speed of the wave changes.*

Refraction

Try this simple activity: Place a pencil in a half-filled glass of water. Now, look at the pencil from the side. The pencil appears to be broken into two pieces! But as you can see when you take the pencil out of the water, it is still in one piece.

What you saw in this experiment was the result of the *refraction* of light waves. **Refraction** is the bending of a wave as the wave passes from one medium to another at an angle. Refraction of a flashlight beam as the beam passes from air to water is shown in **Figure 2.**

refraction the bending of a wave as the wave passes between two substances in which the speed of the wave differs

When a wave moves from one medium to another, the wave's speed changes. When a wave enters a new medium, the wave changes wavelength as well as speed. As a result, the wave bends and travels in a new direction.

Reading Check **What happens to a wave when it moves from one medium to another?** (*See the Appendix for answers to Reading Checks.*)

Refraction of Different Colors

When light waves from the sun pass through a droplet of water in a cloud or through a prism, the light is refracted. But the different colors in sunlight are refracted by different amounts, so the light is *dispersed,* or spread out, into its separate colors. When sunlight is refracted this way through water droplets, you can see a rainbow. Why does that happen?

Although all light waves travel at the same speed through empty space, when light passes through a medium such as water or glass, the speed of the light wave depends on the wavelength of the light wave. Because the different colors of light have different wavelengths, their speeds are different, and they are refracted by different amounts. As a result, the colors are spread out, so you can see them individually.

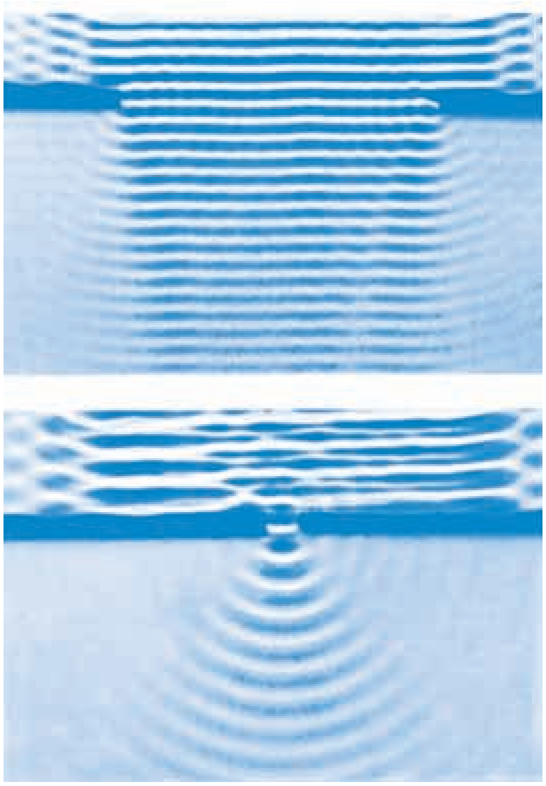
CONNECTION TO Language Arts

WRITING SKILL **The Colors of the Rainbow** People have always been fascinated by the beautiful array of colors that results when sunlight strikes water droplets in the air to form a rainbow. The knowledge science gives us about how they form makes them no less breathtaking.

In the library, find a poem that you like about rainbows. In your **science journal,** copy the poem, and write a paragraph in which you discuss how your knowledge of refraction affects your opinion about the poem.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 3 **Diffraction Through an Opening**



If the barrier or opening is larger than the wavelength of the wave, there is only a small amount of diffraction.

If the barrier or opening is the same size or smaller than the wavelength of an approaching wave, the amount of diffraction is large.

SCHOOL to HOME

What if Light Diffracted?
With an adult, take a walk around your neighborhood. Light waves diffract around corners of buildings much less than sound waves do. Imagine what would happen if light waves diffracted around corners much more than sound waves did. Write a paragraph in your **science journal** describing how this would change what you see and hear as you walk around your neighborhood.

ACTIVITY

Diffraction

Suppose you are walking down a city street and you hear music. The sound seems to be coming from around the corner, but you cannot see where the music is coming from because a building on the corner blocks your view. Why do sound waves travel around a corner better than light waves do?

Most of the time, waves travel in straight lines. For example, a beam of light from a flashlight is fairly straight. But in some circumstances, waves curve or bend when they reach the edge of an object. The bending of waves around a barrier or through an opening is known as **diffraction.**

diffraction a change in the direction of a wave when the wave finds an obstacle or an edge, such as an opening

If You Can Hear It, Why Can't You See It?

The amount of diffraction of a wave depends on its wavelength and the size of the barrier or opening the wave encounters, as shown in **Figure 3.** You can hear music around the corner of a building because sound waves have long wavelengths and are able to diffract around corners. However, you cannot see who is playing the music because the wavelengths of light waves are much shorter than sound waves, so light is not diffracted very much.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Interference

You know that all matter has volume. Therefore, objects cannot be in the same space at the same time. But waves are energy, not matter. So, more than one wave can be in the same place at the same time. In fact, two waves can meet, share the same space, and pass through each other! When two or more waves share the same space, they overlap. The result of two or more waves overlapping is called **interference. Figure 4** shows what happens when waves occupy the same space and interfere with each other.

interference the combination of two or more waves that results in a single wave

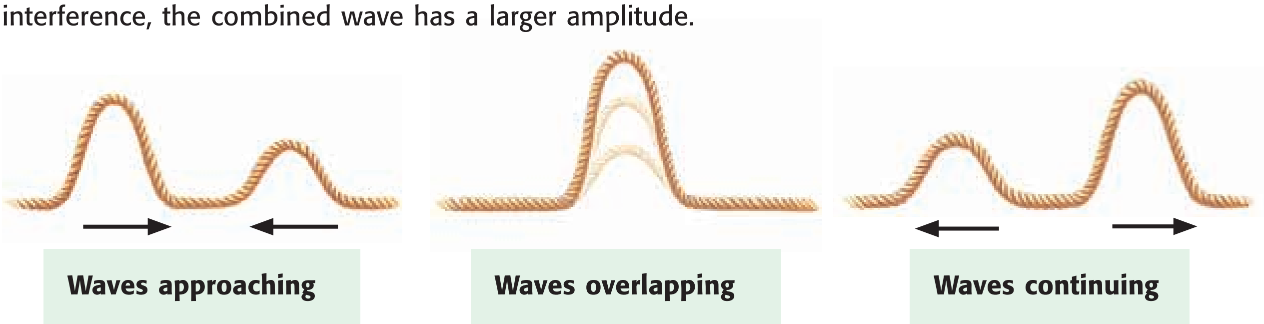
Constructive Interference

Constructive interference happens when the crests of one wave overlap the crests of another wave or waves. The troughs of the waves also overlap. When waves combine in this way, the energy carried by the waves is also able to combine. The result is a new wave that has higher crests and deeper troughs than the original waves had. In other words, the resulting wave has a larger amplitude than the original waves had.

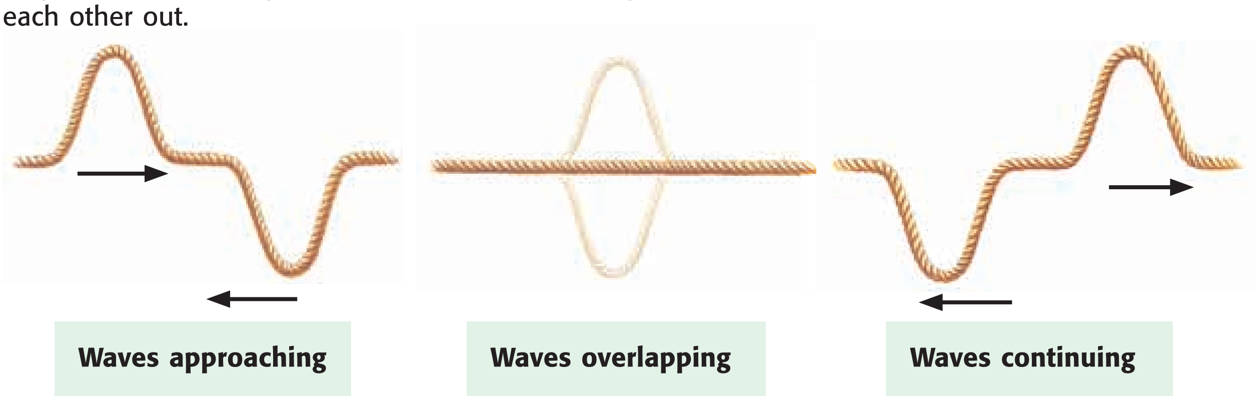
Reading Check **How does constructive interference happen?**

Figure 4 Constructive and Destructive Interference

Constructive Interference When waves combine by constructive interference, the combined wave has a larger amplitude.



Destructive Interference When two waves with the same amplitude combine by destructive interference, they cancel each other out.



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Destructive Interference

Destructive interference happens when the crests of one wave and the troughs of another wave overlap. The new wave has a smaller amplitude than the original waves had. When the waves involved in destructive interference have the same amplitude and meet each other at just the right time, the result is no wave at all.

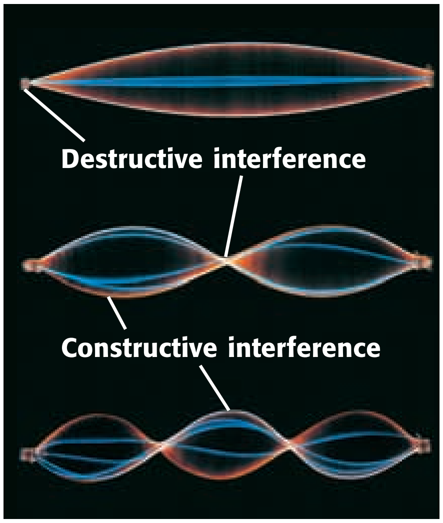


Figure 5 *When you move a rope at certain frequencies, you can create different standing waves.*

Standing Waves

If you tie one end of a rope to the back of a chair and move the other end up and down, the waves you make go down the rope and are reflected back. If you move the rope at certain frequencies, the rope appears to vibrate in loops, as shown in **Figure 5.** The loops come from the interference between the wave you made and the reflected wave. The resulting wave is called a **standing wave.** In a standing wave, certain parts of the wave are always at the rest position because of total destructive interference between all the waves. Other parts have a large amplitude because of constructive interference.

A standing wave only *looks* as if it is standing still. Waves are actually going in both directions. Standing waves can be formed with transverse waves, such as when a musician plucks a guitar string, as well as with longitudinal waves.

Reading Check **How can interference and reflection cause standing waves?**

Figure 6 *A marimba produces notes through the resonance of air columns.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Resonance

The frequencies at which standing waves are made are called *resonant frequencies*. When an object vibrating at or near the resonant frequency of a second object causes the second object to vibrate, **resonance** occurs. A resonating object absorbs energy from the vibrating object and vibrates, too. An example of resonance is shown in **Figure 6** on the previous page.

You may be familiar with another example of resonance at home—in your shower. When you sing in the shower, certain frequencies create standing waves in the air that fills the shower stall. The air resonates in much the same way that the air column in a marimba does. The amplitude of the sound waves becomes greater. So your voice sounds much louder.

standing wave a pattern of vibration that simulates a wave that is standing still

resonance a phenomenon that occurs when two objects naturally vibrate at the same frequency; the sound produced by one object causes the other object to vibrate

SECTION Review

Summary

- Waves reflect after hitting a barrier.
- Refraction is the bending of a wave when it passes through different media.
- Waves bend around barriers or through openings during diffraction.
- The result of two or more waves overlapping is called interference.
- Amplitude increases during constructive interference and decreases during destructive interference.
- Resonance occurs when a vibrating object causes another object to vibrate at one of its resonant frequencies.

Using Key Terms

Complete each of the following sentences by choosing the correct term from the word bank.

refraction   reflection
diffraction   interference

1. ___ happens when a wave passes from one medium to another at an angle.
2. The bending of a wave around a barrier is called ___.
3. We can see the moon because of the ___ of sunlight off it.

Understanding Key Ideas

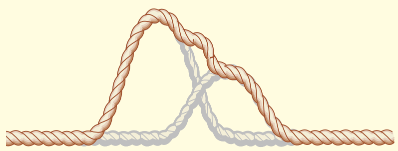
4. The combining of waves as they overlap is known as
   a. interference.
   b. diffraction.
   c. refraction.
   d. resonance.
5. Name two wave interactions that can occur when a wave encounters a barrier.
6. Explain why you can hear two people talking even after they walk around a corner.
7. Explain what happens when two waves encounter one another in destructive interference.

Critical Thinking

8. **Making Inferences** Sometimes, when music is played loudly, you can feel your body shake. Explain what is happening in terms of resonance.
9. **Applying Concepts** How could two waves on a rope interfere so that the rope did not move at all?

Interpreting Graphics

10. In the image below, what sort of wave interaction is happening?



SCILINKS® NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Interactions of Waves
SciLinks code: HSM0304

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Using Scientific Methods

Skills Practice Lab

Wave Energy and Speed

If you threw a rock into a pond, waves would carry energy away from the point of origin. But if you threw a large rock into a pond, would the waves carry more energy away from the point of origin than waves caused by a small rock? And would a large rock make waves that move faster than waves made by a small rock? In this lab, you'll answer these questions.

OBJECTIVES

Form hypotheses about the energy and speed of waves.

Test your hypotheses by performing an experiment.

MATERIALS

- beaker, small
- newspaper
- pan, shallow, approximately 20 cm × 30 cm
- pencils (2)
- stopwatch
- water

SAFETY

Ask a Question

1. In this lab, you will answer the following questions: Do waves made by a large disturbance carry more energy than waves made by a small disturbance? Do waves created by a large disturbance travel faster than waves created by a small disturbance?

Form a Hypothesis

2. Write a few sentences that answer the questions above.

Test the Hypothesis

3. Place the pan on a few sheets of newspaper. Using the small beaker, fill the pan with water.

4. Make sure that the water is still. Tap the surface of the water with the eraser end of one pencil. This tap represents the small disturbance. Record your observations about the size of the waves that are made and the path they take.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

5. Repeat step 4. This time, use the stopwatch to record the amount of time it takes for one of the waves to reach the side of the pan. Record your data.

6. Using two pencils at once, repeat steps 4 and 5. These taps represent the large disturbance. (Try to use the same amount of force to tap the water that you used with just one pencil.) Observe and record your results.

Analyze the Results

1. **Describing Events** Compare the appearance of the waves created by one pencil with that of the waves created by two pencils. Were there any differences in amplitude (wave height)?

2. **Describing Events** Compare the amount of time required for the waves to reach the side of the pan. Did the waves travel faster when two pencils were used?

Draw Conclusions

3. **Drawing Conclusions** Do waves made by a large disturbance carry more energy than waves made by a small one? Explain your answer, using your results to support your answer. (Hint: Remember the relationship between amplitude and energy.)

4. **Drawing Conclusions** Do waves made by a large disturbance travel faster than waves made by a small one? Explain your answer.

Applying Your Data

A tsunami is a giant ocean wave that can reach a height of 30 m. Tsunamis that reach land can cause injury and enormous property damage. Using what you learned in this lab about wave energy and speed, explain why tsunamis are so dangerous. How do you think scientists can predict when tsunamis will reach land?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Chapter Review

USING KEY TERMS

For each pair of terms, explain how the meanings of the terms differ.

1. *longitudinal wave* and *transverse wave*
2. *wavelength* and *amplitude*
3. *reflection* and *refraction*

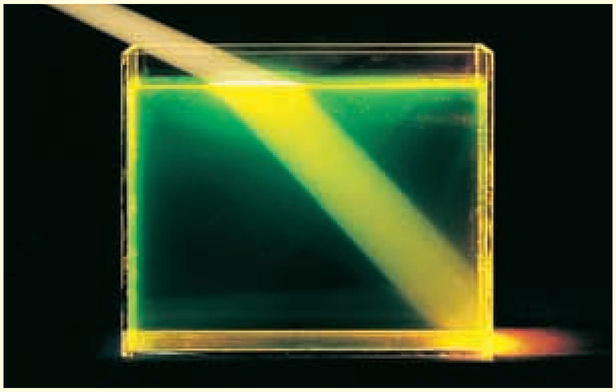
UNDERSTANDING KEY IDEAS

Multiple Choice

4. As the wavelength increases, the frequency
   - **a.** decreases.
   - **b.** increases.
   - **c.** remains the same.
   - **d.** increases and then decreases.

5. Waves transfer
   - **a.** matter.
   - **b.** energy.
   - **c.** particles.
   - **d.** water.

6. Refraction occurs when a wave enters a new medium at an angle because
   - **a.** the frequency changes.
   - **b.** the amplitude changes.
   - **c.** the wave speed changes.
   - **d.** None of the above



7. The wave property that is related to the height of a wave is the
   - **a.** wavelength.
   - **b.** amplitude.
   - **c.** frequency.
   - **d.** wave speed.

8. During constructive interference,
   - **a.** the amplitude increases.
   - **b.** the frequency decreases.
   - **c.** the wave speed increases.
   - **d.** All of the above

9. Waves that don't require a medium are
   - **a.** longitudinal waves.
   - **b.** electromagnetic waves.
   - **c.** surface waves.
   - **d.** mechanical waves.

Short Answer

10. Draw a transverse wave and a longitudinal wave. Label a crest, a trough, a compression, a rarefaction, and wavelengths. Also, label the amplitude on the transverse wave.

11. What is the relationship between frequency, wave speed, and wavelength?

Math Skills

12. A fisherman in a row boat notices that one wave crest passes his fishing line every 5 s. He estimates the distance between the crests to be 1.5 m and estimates that the crests of the waves are 0.5 m above the troughs. Using this data, determine the amplitude and speed of the waves.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

CRITICAL THINKING

13. **Concept Mapping** Use the following terms to create a concept map: *wave, refraction, transverse wave, longitudinal wave, wavelength, wave speed,* and *diffraction*.

14. **Analyzing Ideas** You have lost the paddles for the canoe you rented, and the canoe has drifted to the center of a pond. You need to get it back to the shore, but you do not want to get wet by swimming in the pond. Your friend suggests that you drop rocks behind the canoe to create waves that will push the canoe toward the shore. Will this solution work? Why or why not?

15. **Applying Concepts** Some opera singers can use their powerful voices to break crystal glasses. To do this, they sing one note very loudly and hold it for a long time. While the opera singer holds the note, the walls of the glass move back and forth until the glass shatters. Explain in terms of resonance how the glass shatters.

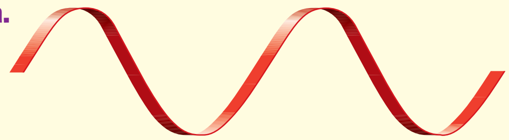
16. **Analyzing Processes** After setting up stereo speakers in your school's music room, you notice that in certain areas of the room, the sound from the speakers is very loud. In other areas, the sound is very soft. Using the concept of interference, explain why the sound levels in the music room vary.

17. **Predicting Consequences** A certain sound wave travels through water with a certain wavelength, frequency, and wave speed. A second sound wave with twice the frequency of the first wave then travels through the same water. What is the second wave's wavelength and wave speed compared to those of the first wave?

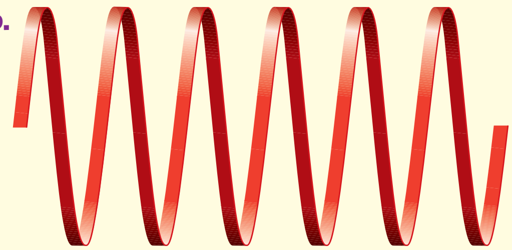
INTERPRETING GRAPHICS

18. Look at the waves below. Rank the waves from highest energy to lowest energy, and explain your reasoning.

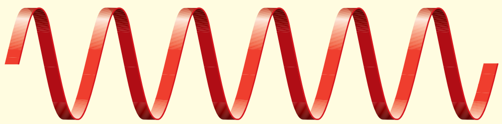
a.



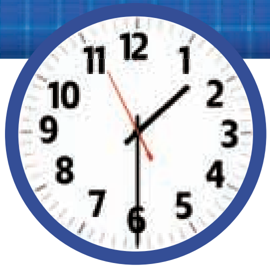
b.



c.



Copyright © by Holt, Rinehart and Winston. All rights reserved.



Standardized Test Preparation

EOG Prep

READING

Read each of the passages below. Then, answer the questions that follow each passage.

Passage 1 On March 27, 1964, a powerful earthquake rocked Alaska. The earthquake started on land near Anchorage, and the seismic waves spread quickly in all directions. The earthquake created a series of ocean waves called <u>tsunamis</u> in the Gulf of Alaska. In the deep water of the gulf, the tsunamis were short and far apart. But as these waves entered the shallow water surrounding Kodiak Island, off the coast of Alaska, they became taller and closer together. Some reached heights of nearly 30 m! The destructive forces of the earthquake and tsunamis killed 21 people and caused $10 million in damage to Kodiak, which made this marine disaster the worst in the town's 200-year history.

1. In the passage, what does *tsunami* mean?

- **A** a seismic wave
- **B** an earthquake
- **C** an ocean wave
- **D** a body of water

2. Which of these events happened first?

- **F** The tsunamis became closer together.
- **G** Tsunamis entered the shallow water.
- **H** Tsunamis formed in the Gulf of Alaska.
- **I** An earthquake began near Anchorage.

3. Which conclusion is **best** supported by information given in the passage?

- **A** Kodiak had never experienced a tsunami before 1964.
- **B** Tsunamis and an earthquake were the cause of Kodiak's worst marine disaster in 200 years.
- **C** Tsunamis are common in Kodiak.
- **D** The citizens of Kodiak went into debt after the 1964 earthquake.

Passage 2 Resonance was partially responsible for the destruction of the Tacoma Narrows Bridge, in Washington. The bridge opened in July 1940 and soon earned the nickname Galloping Gertie because of its wavelike motions. These motions were created by wind that blew across the bridge. The wind caused vibrations that were close to a resonant frequency of the bridge. Because the bridge was in resonance, it absorbed a large amount of energy from the wind, which caused it to vibrate with a large amplitude. On November 7, 1940, a supporting cable slipped, and the bridge began to twist. The twisting of the bridge, combined with high winds, further increased the amplitude of the bridge's motion. Within hours, the amplitude became so great that the bridge collapsed. Luckily, all of the people on the bridge that day were able to escape before it crashed into the river below.

1. What caused wavelike motions in the Tacoma Narrows Bridge?

- **A** wind that caused vibrations that were close to the resonant frequency of the bridge
- **B** vibrations from cars going over the bridge
- **C** twisting of a broken support cable
- **D** an earthquake

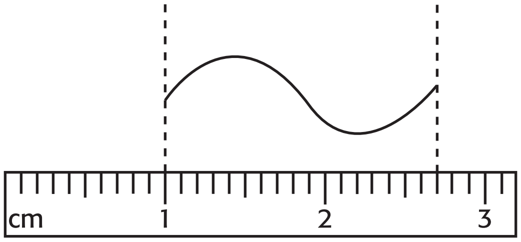
2. Why did the bridge collapse?

- **F** A supporting cable slipped.
- **G** It absorbed a great amount of energy from the wind.
- **H** The amplitude of the bridge's vibrations became great enough.
- **I** Wind blew across it.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

INTERPRETING GRAPHICS

Use the figure below to answer the questions that follow.



1. This wave was generated in a laboratory investigation. What is the wavelength of the wave?
   A 1.5 cm
   B 1.7 cm
   C 2.0 cm
   D 2.7 cm

2. If the frequency of the wave shown were doubled, what would the wavelength of the wave be?
   F 0.85 cm
   G 1.35 cm
   H 3.4 cm
   I 5.4 cm

3. What is the amplitude of the wave shown?
   A 0.85 cm
   B 1.7 cm
   C 2.7 cm
   D There is not enough information to determine the answer.

MATH

Read each question below, and choose the best answer.

1. How is the product of $5 \times 5 \times 5 \times 2 \times 2 \times 2 \times 2$ expressed in exponential notation?
   A $3^5 \times 4^2$
   B $5^3 \times 2^4$
   C $5^7 \times 2^7$
   D 10^7

2. Mannie purchased 8.9 kg of dog food from the veterinarian. How many grams of dog food did he purchase?
   F 8,900 g
   G 890 g
   H 89 g
   I 0.89 g

3. What is the area of a rectangle whose sides are 3 cm long and 7.5 cm long?
   A 10.5 cm^2
   B 12 cm^2
   C 21 cm^2
   D 22.5 cm^2

4. An underwater sound wave traveled 1.5 km in 1 s. How far would it travel in 4 s?
   F 5.0 km
   G 5.5 km
   H 6.0 km
   I 6.5 km

5. During a tennis game, the person serving the ball is allowed only 2 serves to start a point. Hannah plays a tennis match and is able to use 50 of her 63 first serves to start a point. What is the **best** estimate of Hannah's first-service percentage?
   A 126%
   B 88%
   C 81.5%
   D 79%

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Science in Action

Science, Technology, and Society

The Ultimate Telescope

The largest telescopes in the world don't depend on visible light, lenses, or mirrors. Instead, they collect radio waves from the far reaches of outer space. One radio telescope, called the Very Large Array (VLA), is located in a remote desert in New Mexico.

Just as you can detect light waves from stars with your eyes, radio waves emitted from objects in space can be detected with radio telescopes. The Very Large Array consists of 27 radio telescopes like the ones in the photo above.

Math ACTIVITY

Radio waves travel about 300,000,000 m/s. The M100 galaxy is about 5.68×10^{23} m away from Earth. How long, in years, does it take radio waves from M100 to be detected by the VLA?

Scientific Discoveries

The Wave Nature of Light

Have you ever wondered what light really is? Many early scientists did. One of them, the great 17th-century scientist Isaac Newton, did some experiments and decided that light consisted of particles. But when experimenting with lenses, Newton observed some things that he could not explain.

Around 1800, the scientist Thomas Young did more experiments on light and found that it diffracted when it passed through slits. Young concluded that light could be thought of as waves. Although scientists were slow to accept this idea, they now know that light is both particle-like and wavelike.

Language Arts ACTIVITY

WRITING SKILL Thomas Young said, "The nature of light is a subject of no material importance to the concerns of life or to the practice of the arts, but it is in many other respects extremely interesting." Write a brief essay in which you answer the following questions: What do you think Young meant? Do you agree with him? How would you respond to his statement?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Careers

Estela Zavala

Ultrasonographer Estela Zavala is a registered diagnostic medical ultrasonographer who works at Austin Radiological Association in Austin, Texas. Most people have seen a picture of a sonogram showing an unborn baby inside its mother's womb. Ultrasound technologists make these images with an ultrasound machine, which sends harmless, high-frequency sound waves into the body. Zavala uses ultrasound to form images of organs in the body. Zavala says about her education, "After graduating from high school, I went to an X-ray school to be licensed as an X-ray technologist. First, I went to an intensive one-month training program. After that, I worked for a licensed radiologist for about a year. Finally, I attended a yearlong ultrasound program at a local community college before becoming fully licensed." What Zavala likes best about her job is being able to help people by finding out what is wrong with them without surgery. Before ultrasound, surgery was the only way to find out about the health of someone's organs.

Social Studies ACTIVITY

WRITING SKILL Research the different ways in which ultrasound technology is used in medical practice today. Write a few paragraphs about what you learn.

go.hrw.com

To learn more about these Science in Action topics, visit go.hrw.com and type in the keyword HP5WAVF.

Current Science

Check out Current Science® articles related to this chapter by visiting go.hrw.com. Just type in the keyword HP5CS20.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

16

The Nature of Sound

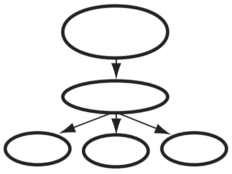
About the PHOTO

Look at these dolphins swimming swiftly and silently through their watery world. Wait a minute—swiftly? Yes. Silently? No way! Dolphins use sound—clicks, squeaks, and other noises—to communicate. Dolphins also use sound to locate their food by echolocation and to find their way through murky water.

PRE-READING ACTIVITY

Graphic Organizer

Concept Map Before you read the chapter, create the graphic organizer entitled "Concept Map" described in the **Study Skills** section of the Appendix. As you read the chapter, fill in the concept map with details about each type of sound interaction.



Copyright © by Holt, Rinehart and Winston. All rights reserved.

START-UP ACTIVITY

A Homemade Guitar

In this chapter, you will learn about sound. You can start by making your own guitar. It won't sound as good as a real guitar, but it will help you explore the nature of sound.

Procedure

1. Stretch a **rubber band** lengthwise around an empty **shoe box.** Place the box hollow side up. Pluck the rubber band gently. Describe what you hear.
2. Stretch **another rubber band of a different thickness** around the box. Pluck both rubber bands. Describe the differences in the sounds.
3. Put a **pencil** across the center of the box and under the rubber bands, and pluck again. Compare this sound with the sound you heard before the pencil was used.
4. Move the pencil closer to one end of the shoe box. Pluck on both sides of the pencil. Describe the differences in the sounds you hear.

Analysis

1. How did the thicknesses of the rubber bands affect the sound?
2. In steps 3 and 4, you changed the length of the vibrating part of the rubber bands. What is the relationship between the vibrating length of the rubber band and the sound that you hear?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 1

What Is Sound?

You are in a restaurant, and without warning, you hear a loud crash. A waiter dropped a tray of dishes. What a mess! But why did dropping the dishes make such a loud sound?

In this section, you'll find out what causes sound and what characteristics all sounds have in common. You'll also learn how your ears detect sound and how you can protect your hearing.

READING WARM-UP

Objectives

- Describe how vibrations cause sound.
- Explain how sound is transmitted through a medium.
- Explain how the human ear works, and identify its parts.
- Identify ways to protect your hearing.

Terms to Learn

sound wave
medium

READING STRATEGY

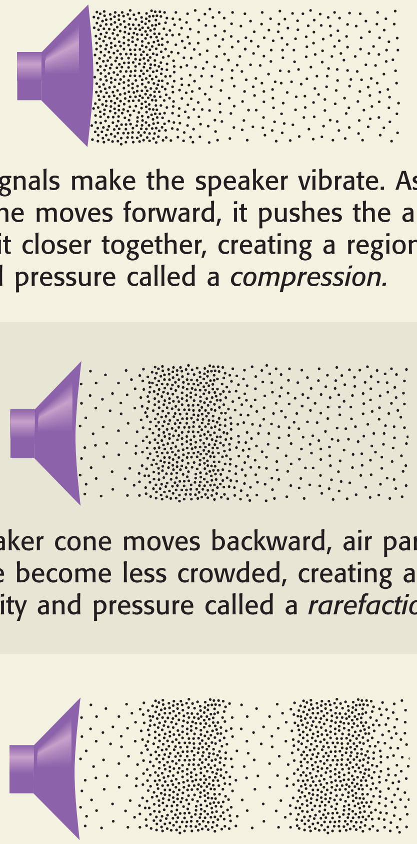
Prediction Guide Before reading this section, predict whether each of the following statements is true or false:

- Sound waves are made by vibrations.
- Sound waves push air particles along until they reach your ear.

Sound and Vibrations

As different as they are, all sounds have some things in common. One characteristic of sound is that it is created by vibrations. A *vibration* is the complete back-and-forth motion of an object or material. **Figure 1** shows one way sound is made by vibrations.

Figure 1 **Sounds from a Stereo Speaker**



a Electrical signals make the speaker vibrate. As the speaker cone moves forward, it pushes the air particles in front of it closer together, creating a region of higher density and pressure called a *compression.*

b As the speaker cone moves backward, air particles close to the cone become less crowded, creating a region of lower density and pressure called a *rarefaction.*

c For each vibration, a compression and a rarefaction are formed. As the compressions and rarefactions travel away from the speaker, sound is transmitted through the air.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 2 *You can't actually see sound waves, but they can be represented by spheres that spread out in all directions.*

Sound Waves

Longitudinal (LAHN juh TOOD'n uhl) waves are made of compressions and rarefactions. A **sound wave** is a longitudinal wave generated by a vibrating material, which is then carried through a substance and transfers energy. The particles of the substance, such as air particles, vibrate back and forth along the path that the sound wave travels. Sound is transmitted through the vibrations and collisions of the particles. Because the particles vibrate back and forth along the paths that sound travels, sound travels as longitudinal waves.

sound wave a longitudinal wave that is caused by vibrations and that travels through a material medium

Sound waves travel in all directions away from their source, as shown in **Figure 2.** However, air or other matter does not travel with the sound waves. The particles of air only vibrate back and forth. If air did travel with sound, wind gusts from music speakers would blow you over at a school dance!

Reading Check **What do sound waves consist of?** (*See the Appendix for answers to Reading Checks.*)

Quick Lab

Good Vibrations

1. Gently strike a **tuning fork** on a **rubber eraser.** Watch the prongs, and listen for a sound. Describe what you see and what you hear.
2. Lightly touch the fork with your fingers. What do you feel?
3. Grasp the prongs of the fork firmly with your hand. What happens to the sound?
4. Strike the tuning fork on the eraser again, and dip the prongs in a **cup of water.** Describe what happens to the water.
5. Record your observations.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 3 Tubing is connected to a pump that is removing air from the jar. As the air is removed, the ringing alarm clock sounds quieter and quieter.

Sound and Media

Another characteristic of sound is that all sound waves require a medium (plural, *media*). A **medium** is a substance through which a wave can travel by vibrating particles in the material. Most of the sounds that you hear travel through air at least part of the time. But sound waves can also travel through other materials, such as water, glass, and metal.

medium a physical environment in which phenomena occur

In a vacuum, however, there are no particles to vibrate. So, no sound can be made in a vacuum. This fact helps to explain the effect described in **Figure 3.** Sound must travel through air or some other medium to reach your ears and be detected.

Reading Check **What does sound need in order to travel?**

CONNECTION TO Biology

Vocal Sounds The vibrations that produce your voice are made inside your throat. When you speak, laugh, or sing, your lungs force air up your windpipe, causing your vocal cords to vibrate.

Do some research, and find out what role different parts of your throat and mouth play in making vocal sounds. Make a poster in which you show the different parts, and explain the role they play in shaping sound waves.

ACTIVITY

How You Detect Sound

Imagine that you are watching a suspenseful movie. Just before a door is opened, the background music becomes louder. You know that there is something scary behind that door! Now, imagine watching the same scene without the sound. You would have more difficulty figuring out what's going on if there were no sound.

Figure 4 shows how your ears change sound waves into electrical signals that allow you to hear. First, the outer ear collects sound waves. The vibrations then go to your middle ear. Very small organs increase the size of the vibrations here. These vibrations are then picked up by organs in your inner ear. Your inner ear changes vibrations into electrical signals that your brain interprets as sound.

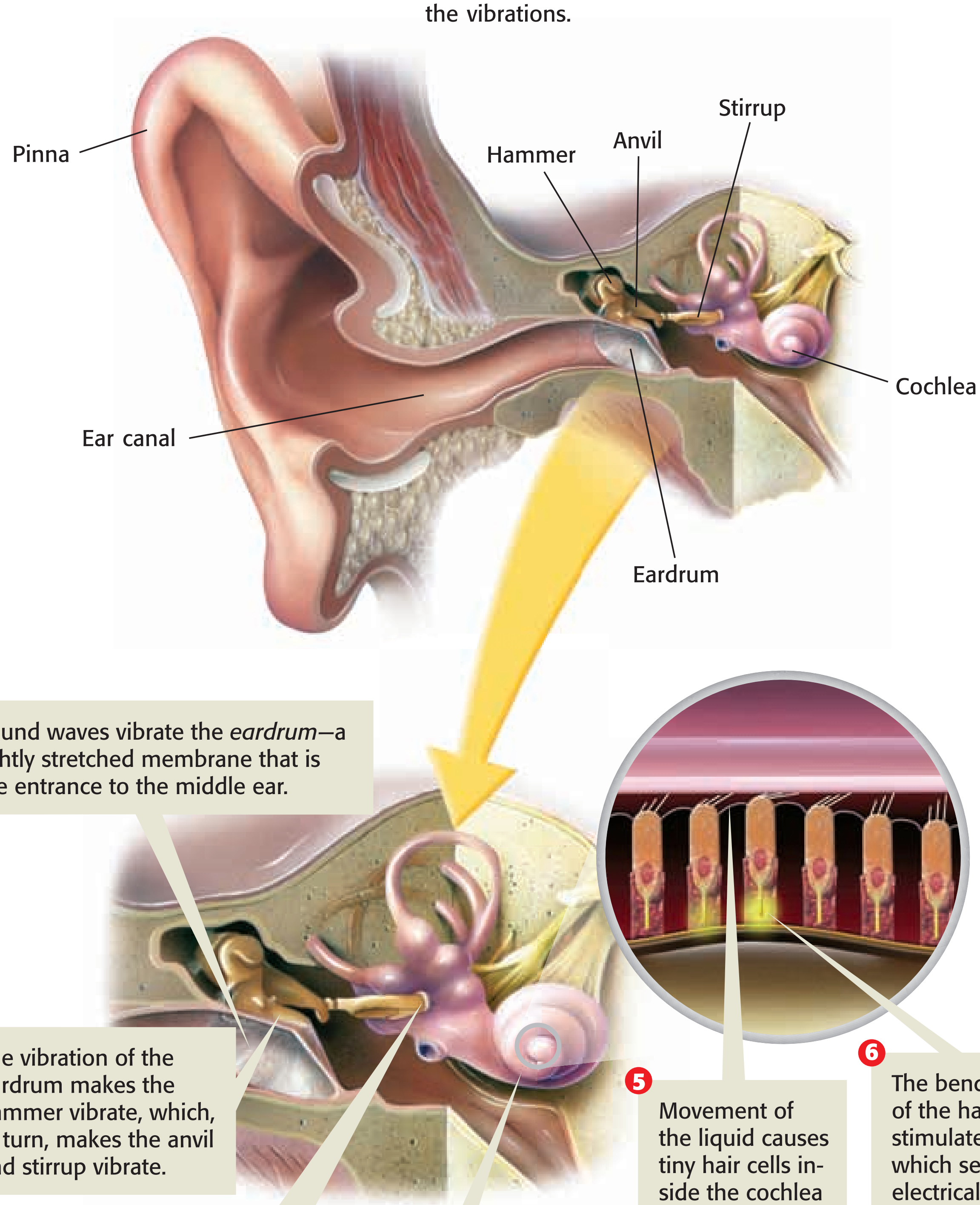
Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 4 How the Human Ear Works

a The **outer ear** acts as a funnel for sound waves. The *pinna* collects sound waves and directs them into the *ear canal.*

b In the **middle ear,** three bones—the *hammer, anvil,* and *stirrup*—act as levers to increase the size of the vibrations.

c In the **inner ear,** vibrations created by sound are changed into electrical signals for the brain to interpret.



1 Sound waves vibrate the *eardrum*—a lightly stretched membrane that is the entrance to the middle ear.

2 The vibration of the eardrum makes the hammer vibrate, which, in turn, makes the anvil and stirrup vibrate.

3 The stirrup vibrates the *oval window*—the entrance to the inner ear.

4 The vibrations of the oval window create waves in the liquid inside the *cochlea.*

5 Movement of the liquid causes tiny hair cells inside the cochlea to bend.

6 The bending of the hair cells stimulates nerves, which send electrical signals to the brain.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 5 *Sound is made whether or not anyone is around to hear it.*

Making Sound Versus Hearing Sound

Have you heard this riddle? If a tree falls in the forest and no one is around to hear it, does the tree make a sound? Think about the situation pictured in **Figure 5.** When a tree falls and hits the ground, the tree and the ground vibrate. These vibrations make compressions and rarefactions in the surrounding air. So, there would be a sound!

Making sound is separate from detecting sound. The fact that no one heard the tree fall doesn't mean that there wasn't a sound. A sound was made—it just wasn't heard.

INTERNET ACTIVITY

For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HP5SNDW.**

Hearing Loss and Deafness

The many parts of the ear must work together for you to hear sounds. If any part of the ear is damaged or does not work properly, hearing loss or deafness may result.

One of the most common types of hearing loss is called *tinnitus* (ti NIET us), which results from long-term exposure to loud sounds. Loud sounds can cause damage to the hair cells and nerve endings in the cochlea. Once these hairs are damaged, they do not grow back. Damage to the cochlea or any other part of the inner ear usually results in permanent hearing loss.

People who have tinnitus often say they have a ringing in their ears. They also have trouble understanding other people and hearing the difference between words that sound alike. Tinnitus can affect people of any age. Fortunately, tinnitus can be prevented.

Reading Check **What causes tinnitus?**

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Protecting Your Hearing

Short exposures to sounds that are loud enough to be painful can cause hearing loss. Your hearing can also be damaged by loud sounds that are not quite painful, if you are exposed to them for long periods of time. There are some simple things you can do to protect your hearing. Loud sounds can be blocked out by earplugs. You can listen at a lower volume when you are using headphones, as in **Figure 6.** You can also move away from loud sounds. If you are near a speaker playing loud music, just move away from it. When you double the distance between yourself and a loud sound, the sound's intensity to your ears will be one-fourth of what it was before.

Figure 6 *Turning your radio down can help prevent hearing loss, especially when you use headphones.*

SECTION Review

Summary

- All sounds are generated by vibrations.
- Sounds travel as longitudinal waves consisting of compressions and rarefactions.
- Sound waves travel in all directions away from their source.
- Sound waves require a medium through which to travel. Sound cannot travel in a vacuum.
- Your ears convert sound into electrical impulses that are sent to your brain.
- Exposure to loud sounds can cause hearing damage.
- Using earplugs and lowering the volume of sounds can prevent hearing damage.

Using Key Terms

1. Use the following terms in the same sentence: *sound wave* and *medium.*

Understanding Key Ideas

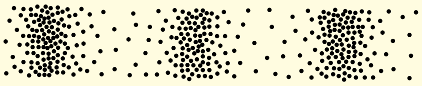
2. Sound travels as
   a. transverse waves.
   b. longitudinal waves.
   c. shock waves.
   d. airwaves.
3. Which part of the ear increases the size of the vibrations of sound waves entering the ear?
   a. outer ear
   b. ear canal
   c. middle ear
   d. inner ear
4. Name two ways of protecting your hearing.

Critical Thinking

5. **Analyzing Processes** Explain why a person at a rock concert will not feel gusts of wind coming out of the speakers.
6. **Analyzing Ideas** If a meteorite crashed on the moon, would you be able to hear it on Earth? Why, or why not?
7. **Identifying Relationships** Recall the breaking dishes mentioned at the beginning of this section. Why was the sound that they made so loud?

Interpreting Graphics

Use the diagram of a wave below to answer the questions that follow.



8. What kind of wave is this?
9. Draw a sketch of the diagram on a separate sheet of paper, and label the compressions and rarefactions.
10. How do vibrations make these kinds of waves?

SCI LINKS. NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: The Ear; What Is Sound?
SciLinks code: HSM0440; HSM1663

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 2

Properties of Sound

Imagine that you are swimming in a neighborhood pool. You can hear the high, loud laughter of small children and the soft splashing of the waves at the edge of the pool.

Why are some sounds loud, soft, high, or low? The differences between sounds depend on the properties of the sound waves. In this section, you will learn about properties of sound.

READING WARM-UP

Objectives

- Compare the speed of sound in different media.
- Explain how frequency and pitch are related.
- Describe the Doppler effect, and give examples of it.
- Explain how amplitude and loudness are related.
- Describe how amplitude and frequency can be "seen" on an oscilloscope.

Terms to Learn

pitch
Doppler effect
loudness
decibel

READING STRATEGY

Reading Organizer As you read this section, create an outline of the section. Use the headings from the section in your outline.

The Speed of Sound

Suppose you are standing at one end of a pool and two people from the opposite end of the pool yell at the same time. You would hear their voices at the same time. The reason is that the speed of sound depends only on the medium in which the sound is traveling. So, you would hear them at the same time—even if one person yelled louder!

How the Speed of Sound Can Change

Table 1 shows how the speed of sound varies in different media. Sound travels quickly through air, but it travels even faster in liquids and even faster in solids.

Temperature also affects the speed of sound. In general, the cooler the medium is, the slower the speed of sound. Particles of cool materials move more slowly and transmit energy more slowly than particles do in warmer materials. In 1947, pilot Chuck Yeager became the first person to travel faster than the speed of sound. Yeager flew the airplane shown in **Figure 1** at 293 m/s (about 480 mi/h) at 12,000 m above sea level. At that altitude, the temperature of the air is so low that the speed of sound is only 290 m/s.

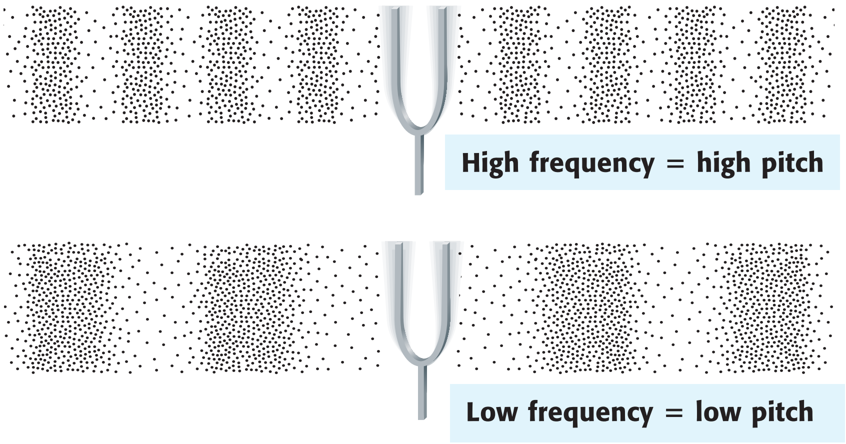
***Table 1* Speed of Sound in Different Media**

Medium	Speed (m/s)
Air (0°C)	331
Air (20°C)	343
Air (100°C)	366
Water (20°C)	1,482
Steel (20°C)	5,200
Oxygen (0°C)	317
Methyl alcohol (25°C)	1,140
Sea water (25°C)	1,530

Figure 1 *The* X-1 *airplane was the first vehicle to move faster than the speed of sound.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 2 Frequency and Pitch



Pitch and Frequency

How low or high a sound seems to be is the **pitch** of that sound. The *frequency* of a wave is the number of crests or troughs that are made in a given time. The pitch of a sound is related to the frequency of the sound wave, as shown in **Figure 2.** Frequency is expressed in hertz (Hz), where 1 Hz = 1 wave per second. For example, the lowest note on a piano is about 40 Hz. The screech of a bat is 10,000 Hz or higher.

pitch a measure of how high or low a sound is perceived to be, depending on the frequency of the sound wave

Reading Check **What is frequency?** (*See the Appendix for answers to Reading Checks.*)

Frequency and Hearing

If you see someone blow a dog whistle, the whistle seems silent to you. The reason is that the frequency of the sound wave is out of the range of human hearing. But the dog hears the whistle and comes running! **Table 2** compares the range of frequencies that humans and animals can hear. Sounds that have a frequency too high for people to hear are called *ultrasonic*.

MATH PRACTICE

The Speed of Sound

The speed of sound depends on the medium through which sound is traveling and the medium's temperature. Sound travels at 343 m/s through air at a temperature of 20°C. How far will sound travel in 20°C air in 5 s?

The speed of sound in steel at 20°C is 5,200 m/s. How far can sound travel in 5 s through steel at 20°C?

Table 2 **Frequencies Heard by Different Animals**

Animal	Frequency range (Hz)
Bat	2,000 to 110,000
Porpoise	75 to 150,000
Cat	45 to 64,000
Beluga whale	1,000 to 123,000
Elephant	16 to 12,000
Human	20 to 20,000
Dog	67 to 45,000

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 3 **The Doppler Effect**

a A car with its horn honking moves toward the sound waves going in the same direction. A person in front of the car hears sound waves that are closer together.

b The car moves away from the sound waves going in the opposite direction. A person behind the car hears sound waves that are farther apart and have a lower frequency.

Doppler effect an observed change in the frequency of a wave when the source or observer is moving

The Doppler Effect

Have you ever been passed by a car with its horn honking? If so, you probably noticed the sudden change in pitch—sort of an *EEEEEOOooowwn* sound—as the car went past you. The pitch you heard was higher as the car moved toward you than it was after the car passed. This higher pitch was a result of the Doppler effect. For sound waves, the **Doppler effect** is the apparent change in the frequency of a sound caused by the motion of either the listener or the source of the sound. **Figure 3** shows how the Doppler effect works.

In a moving sound source, such as a car with its horn honking, sound waves that are moving forward are going the same direction the car is moving. As a result, the compressions and rarefactions of the sound wave will be closer together than they would be if the sound source was not moving. To a person in front of the car, the frequency and pitch of the sound seem high. After the car passes, it is moving in the opposite direction that the sound waves are moving. To a person behind the car, the frequency and pitch of the sound seem low. The driver always hears the same pitch because the driver is moving with the car.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Loudness and Amplitude

If you gently tap a drum, you will hear a soft rumbling. But if you strike the drum with a large force, you will hear a much louder sound! By changing the force you use to strike the drum, you change the loudness of the sound that is created. **Loudness** is a measure of how well a sound can be heard.

Energy and Vibration

Look at **Figure 4.** The harder you strike a drum, the louder the boom. As you strike the drum harder, you transfer more energy to the drum. The drum moves with a larger vibration and transfers more energy to the air around it. This increase in energy causes air particles to vibrate farther from their rest positions.

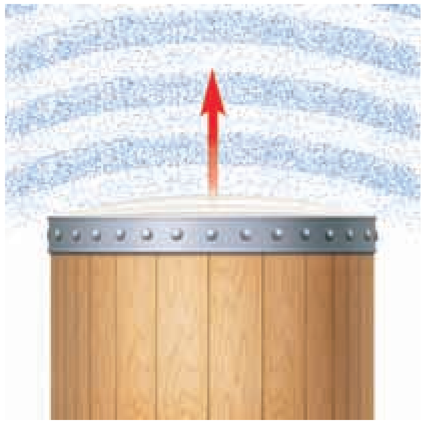


Figure 4 *When a drum is struck hard, it vibrates with a lot of energy, making a loud sound.*

Increasing Amplitude

When you strike a drum harder, you are increasing the amplitude of the sound waves being made. The *amplitude* of a wave is the largest distance the particles in a wave vibrate from their rest positions. The larger the amplitude, the louder the sound. And the smaller the amplitude, the softer the sound. One way to increase the loudness of a sound is to use an amplifier, shown in **Figure 5.** An amplifier receives sound signals in the form of electric current. The amplifier then increases the energy and makes the sound louder.

loudness the extent to which a sound can be heard

Reading Check **What is the relationship between the amplitude of a sound and its energy of vibration?**

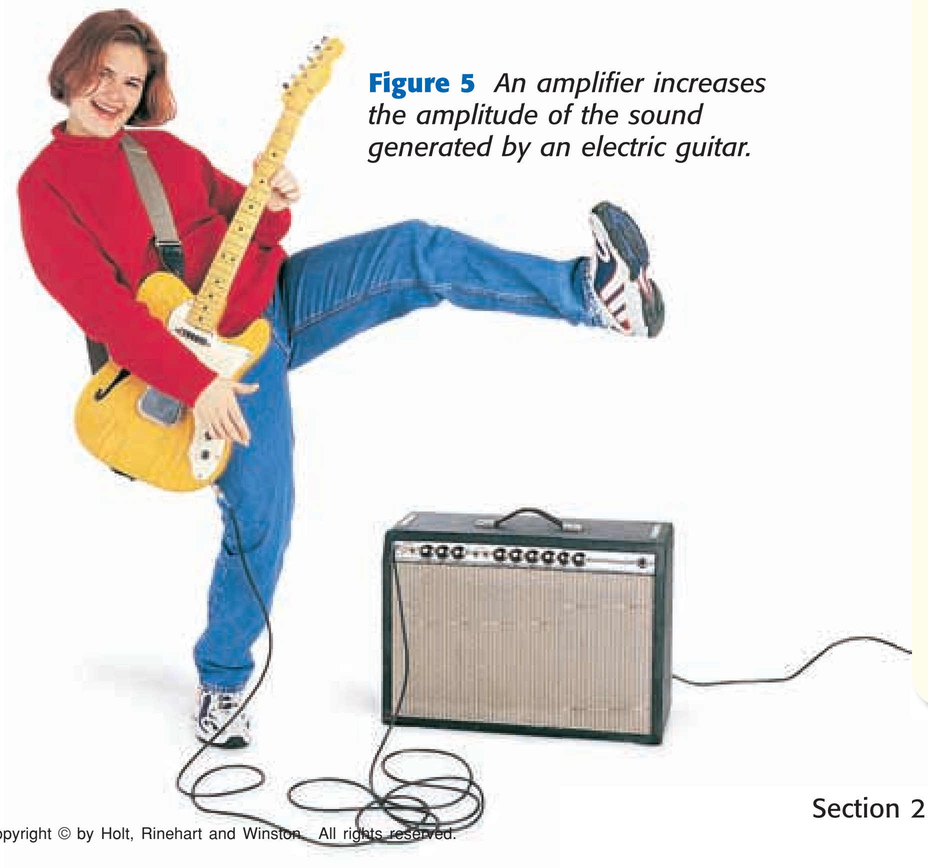


Figure 5 *An amplifier increases the amplitude of the sound generated by an electric guitar.*

QuickLab

Sounding Board

1. With one hand, hold a **ruler** on your **desk** so that one end of it hangs over the edge.
2. With your other hand, pull the free end of the ruler up a few centimeters, and let go.
3. Try pulling the ruler up different distances. How does the distance affect the sounds you hear? What property of the sound wave are you changing?
4. Change the length of the part that hangs over the edge. What property of the sound wave is affected? Record your answers and observations.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SCHOOL to HOME

WRITING SKILL **Decibel Levels**

With a parent, listen for the normal sounds that happen around your house. In your **science journal,** write down some sounds and what you think their decibel levels might be. Then, move closer to the source of each sound, and write what you think the new decibel level of each is.

ACTIVITY

Table 3 **Decibel Levels of Common Sounds**

Decibel level	Sound
0	the softest sounds you can hear
20	whisper
25	purring cat
60	normal conversation
80	lawn mower, vacuum cleaner, truck traffic
100	chain saw, snowmobile
115	sandblaster, loud rock concert, automobile horn
120	threshold of pain
140	jet engine 30 m away
200	rocket engine 50 m away

decibel the most common unit used to measure loudness (symbol, dB)

Measuring Loudness

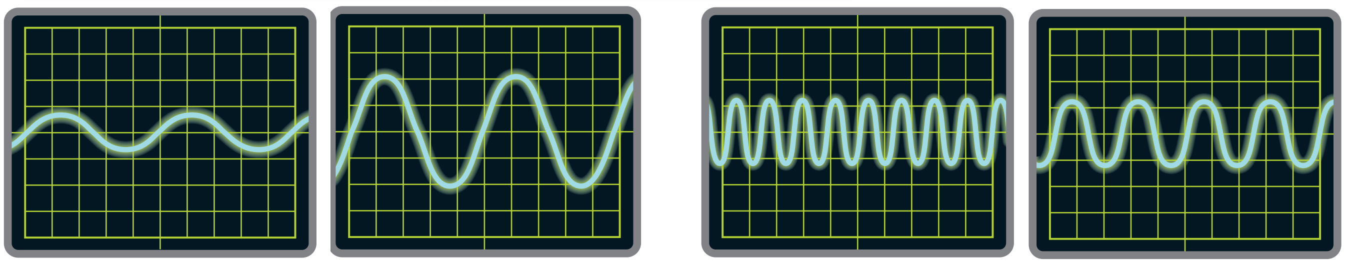
The most common unit used to express loudness is the **decibel** (dB). The softest sounds an average human can hear are at a level of 0 dB. Sounds that are at 120 dB or higher can be painful. **Table 3** shows some common sounds and their decibel levels.

"Seeing" Amplitude and Frequency

Sound waves are invisible. However, technology can provide a way to "see" sound waves. A device called an *oscilloscope* (uh SIL uh SKOHP) can graph representations of sound waves, as shown in **Figure 6.** Notice that the graphs look like transverse waves instead of longitudinal waves.

Reading Check **What does an oscilloscope do?**

Figure 6 **"Seeing" Sounds**



The graph on the right has a **larger amplitude** than the graph on the left. So, the sound represented on the right is **louder** than the one represented on the left.

The graph on the right has a **lower frequency** than the one on the left. So, the sound represented on the right has a **lower pitch** than the one represented on the left.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

From Sound to Electrical Signal

An oscilloscope is shown in **Figure 7.** A microphone is attached to the oscilloscope and changes a sound wave into an electrical signal. The electrical signal is graphed on the screen in the form of a wave. The graph shows the sound as if it were a transverse wave. So, the sound's amplitude and frequency are easier to see. The highest points (crests) of these waves represent compressions, and the lowest points (troughs) represent rarefactions. By looking at the displays on the oscilloscope, you can quickly see the differences in amplitude and frequency of different sound waves.

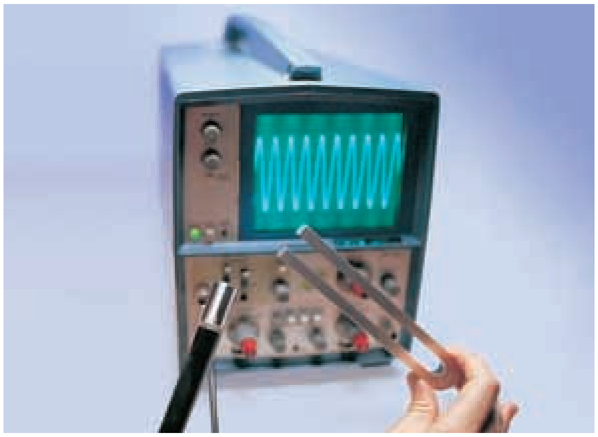


Figure 7 *An oscilloscope can be used to represent sounds.*

SECTION Review

Summary

- The speed of sound depends on the medium and the temperature.
- The pitch of a sound becomes higher as the frequency of the sound wave becomes higher. Frequency is expressed in units of Hertz (Hz), which is equivalent to waves per second.
- The Doppler effect is the apparent change in frequency of a sound caused by the motion of either the listener or the source of the sound.
- Loudness increases with the amplitude of the sound. Loudness is expressed in decibels.
- The amplitude and frequency of a sound can be measured electronically by an oscilloscope.

Using Key Terms

1. In your own words, write a definition for the term *pitch.*
2. Use the following terms in the same sentence: *loudness* and *decibel.*

Understanding Key Ideas

3. At the same temperature, in which medium does sound travel fastest?
   a. air
   b. liquid
   c. solid
   d. It travels at the same speed through all media.
4. In general, how does the temperature of a medium affect the speed of sound through that medium?
5. What property of waves affects the pitch of a sound?
6. How does an oscilloscope allow sound waves to be "seen"?

Math Skills

7. You see a distant flash of lightning, and then you hear a thunderclap 2 s later. The sound of the thunder moves at 343 m/s. How far away was the lightning?
8. In water that is near 0°C, a submarine sends out a sonar signal (a sound wave). The signal travels 1500 m/s and reaches an underwater mountain in 4 s. How far away is the mountain?

Critical Thinking

9. **Analyzing Processes** Will a listener notice the Doppler effect if both the listener and the source of the sound are traveling toward each other? Explain your answer.
10. **Predicting Consequences** A drum is struck gently, then is struck harder. What will be the difference in the amplitude of the sounds made? What will be the difference in the frequency of the sounds made?

SCILINKS® NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Properties of Sound
SciLinks code: HSM1233

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 3

Interactions of Sound Waves

Have you ever heard of a sea canary? It's not a bird! It's a whale! Beluga whales are sometimes called sea canaries because of the many different sounds they make.

Dolphins, beluga whales, and many other animals that live in the sea use sound to communicate. Beluga whales also rely on reflected sound waves to find fish, crabs, and shrimp to eat. In this section, you will learn about reflection and other interactions of sound waves. You will also learn how bats, dolphins, and whales use sound to find food.

READING WARM-UP

Objectives

- Explain how echoes are made, and describe their use in locating objects.
- List examples of constructive and destructive interference of sound waves.
- Explain what resonance is.

Terms to Learn

echo	sonic boom
echolocation	standing wave
interference	resonance

READING STRATEGY

Paired Summarizing Read this section silently. In pairs, take turns summarizing the material. Stop to discuss ideas that seem confusing.

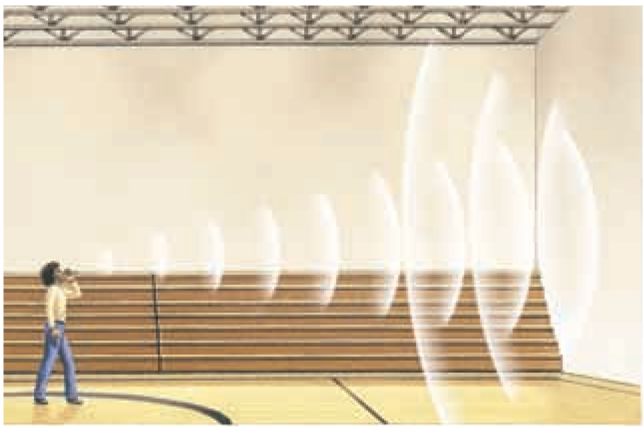
Reflection of Sound Waves

Reflection is the bouncing back of a wave after it strikes a barrier. You're probably already familiar with a reflected sound wave, otherwise known as an **echo.** The strength of a reflected sound wave depends on the reflecting surface. Sound waves reflect best off smooth, hard surfaces. Look at **Figure 1.** A shout in an empty gymnasium can produce an echo, but a shout in an auditorium usually does not.

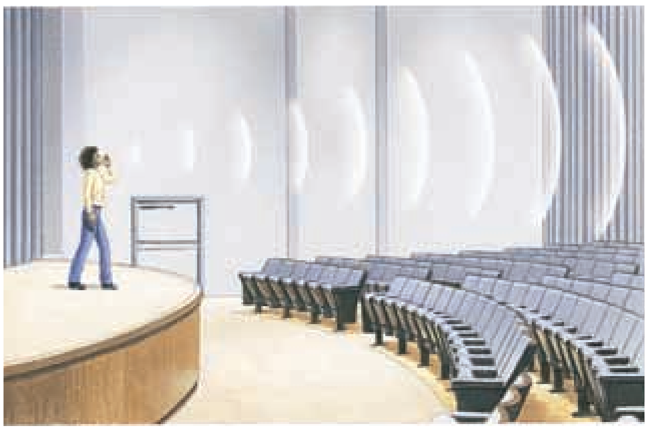
The difference is that the walls of an auditorium are usually designed so that they absorb sound. If sound waves hit a flat, hard surface, they will reflect back. Reflection of sound waves doesn't matter much in a gymnasium. But you don't want to hear echoes while listening to a musical performance!

echo a reflected sound wave

Figure 1 Sound Reflection and Absorption



Sound waves easily reflect off the smooth, hard walls of a gymnasium. For this reason, you hear an echo.



In well-designed auditoriums, echoes are reduced by soft materials that absorb sound waves and by irregular shapes that scatter sound waves.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

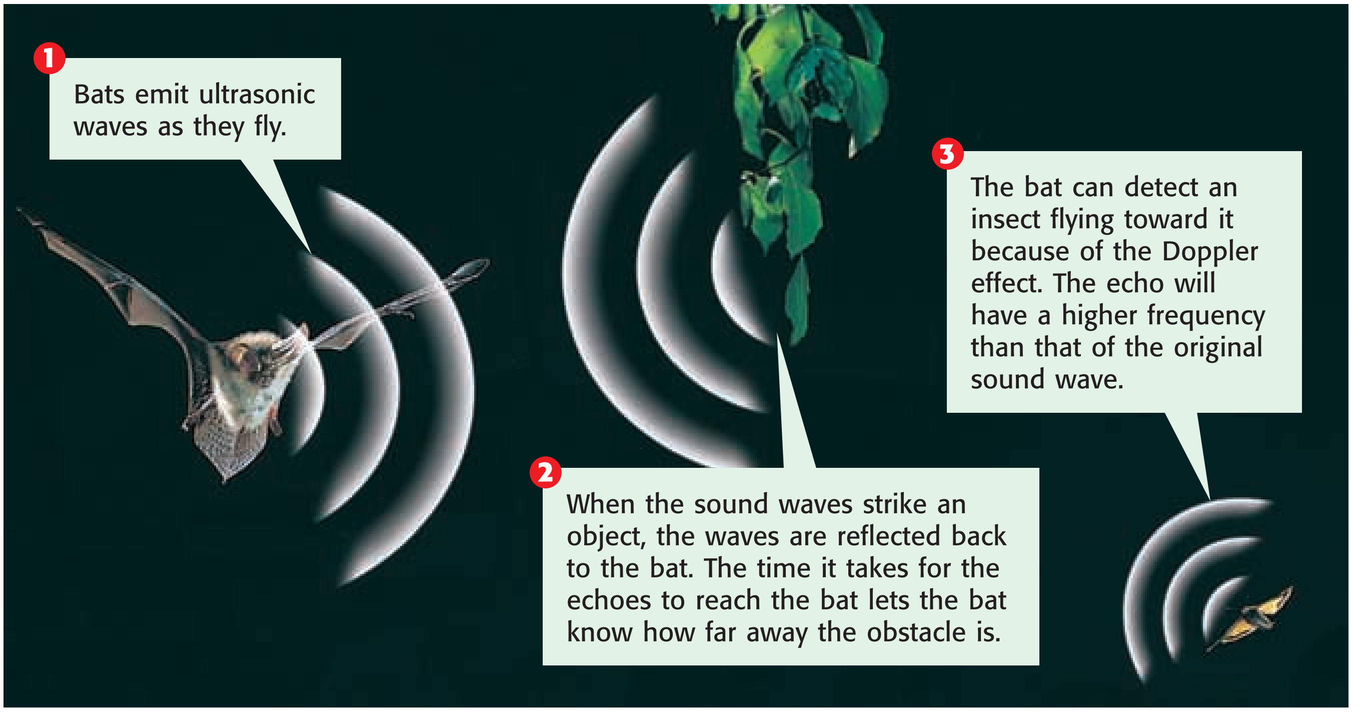


Figure 2 *Bats use echolocation to navigate around barriers and to find insects to eat.*

Echolocation

Beluga whales use echoes to find food. The use of reflected sound waves to find objects is called **echolocation.** Other animals—such as dolphins, bats, and some kinds of birds—also use echolocation to hunt food and to find objects in their paths. **Figure 2** shows how echolocation works. Animals that use echolocation can tell how far away something is based on how long it takes sound waves to echo back to their ears. Some animals, such as bats, also make use of the Doppler effect to tell if another moving object, such as an insect, is moving toward it or away from it.

echolocation the process of using reflected sound waves to find objects; used by animals such as bats

Reading Check **How is echolocation useful to some animals?** (*See the Appendix for answers to Reading Checks.*)

Echolocation Technology

People use echoes to locate objects underwater by using sonar (which stands for **so**und **n**avigation **a**nd **r**anging). *Sonar* is a type of electronic echolocation. **Figure 3** shows how sonar works. Ultrasonic waves are used because their short wavelengths give more details about the objects they reflect off. Sonar can also help navigators on ships avoid icebergs and can help oceanographers map the ocean floor.

Figure 3 *A fish finder sends ultrasonic waves down into the water. The time it takes for the echo to return helps determine the location of the fish.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 4 *Images created by ultrasonography are fuzzy, but they are a safe way to see inside a patient's body.*

Ultrasonography

Ultrasonography (UHL truh soh NAHG ruh fee) is a medical procedure that uses echoes to "see" inside a patient's body without doing surgery. A special device makes ultrasonic waves with a frequency that can be from 1 million to 10 million hertz, which reflect off the patient's internal organs. These echoes are then changed into images that can be seen on a television screen, as shown in **Figure 4.** Ultrasonography is used to examine kidneys, gallbladders, and other organs. It is also used to check the development of an unborn baby in a mother's body. Ultrasonic waves are less harmful to human tissue than X rays are.

interference the combination of two or more waves that results in a single wave

sonic boom the explosive sound heard when a shock wave from an object traveling faster than the speed of sound reaches a person's ears

Interference of Sound Waves

Sound waves also interact through interference. **Interference** happens when two or more waves overlap. **Figure 5** shows how two sound waves can combine by both constructive and destructive interference.

Orchestras and bands make use of constructive interference when several instruments of the same kind play the same notes. Interference of the sound waves causes the combined amplitude to increase, resulting in a louder sound. But destructive interference may keep some members of the audience from hearing the concert well. In certain places in an auditorium, sound waves reflecting off the walls interfere destructively with the sound waves from the stage.

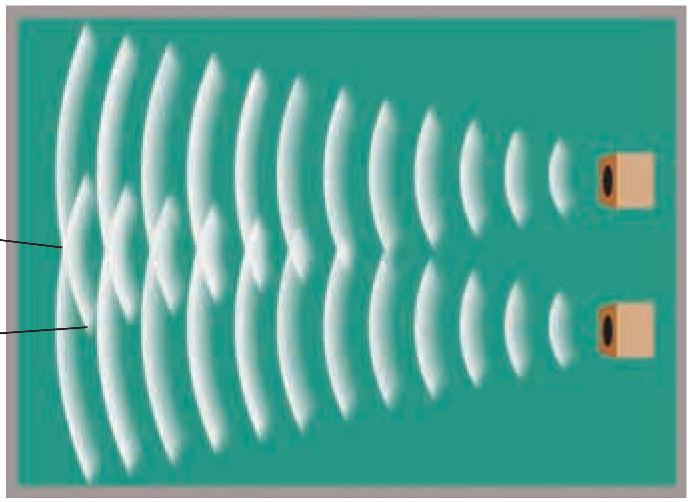
Reading Check **What are the two kinds of sound wave interference?**

Figure 5 **Constructive and Destructive Interference**

Sound waves from two speakers producing sound of the same frequency combine by both constructive and destructive interference.

Constructive Interference
As the compressions of one wave overlap the compressions of another wave, the sound will be louder because the amplitude is increased.

Destructive Interference
As the compressions of one wave overlap the rarefactions of another wave, the sound will be softer because the amplitude is decreased.



Copyright © by Holt, Rinehart and Winston. All rights reserved.

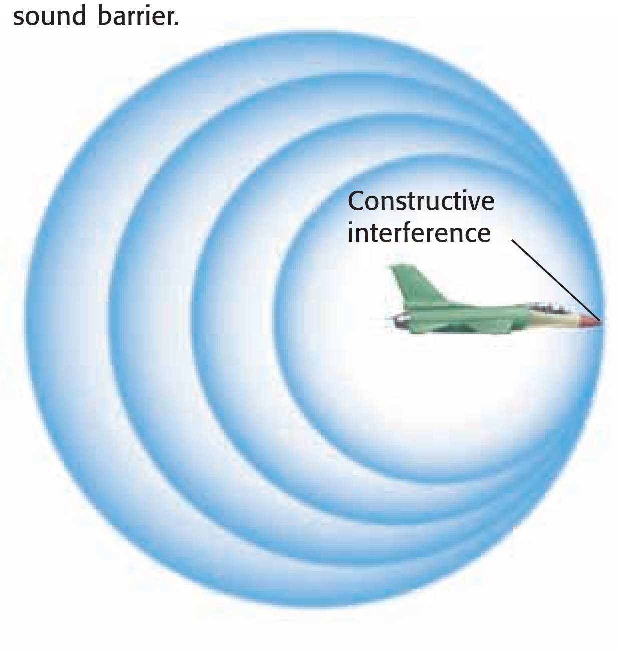
Interference and the Sound Barrier

As the source of a sound—such as a jet plane—gets close to the speed of sound, the sound waves in front of the jet plane get closer and closer together. The result is constructive interference. **Figure 6** shows what happens as a jet plane reaches the speed of sound.

For the jet in **Figure 6** to go faster than the speed of sound, the jet must overcome the pressure of the compressed sound waves. **Figure 7** shows what happens as soon as the jet reaches supersonic speeds—speeds faster than the speed of sound. At these speeds, the sound waves trail off behind the jet. At their outer edges, the sound waves combine by constructive interference to form a *shock wave*.

A **sonic boom** is the explosive sound heard when a shock wave reaches your ears. Sonic booms can be so loud that they can hurt your ears and break windows. They can even make the ground shake as it does during an earthquake.

Figure 6 *When a jet plane reaches the speed of sound, the sound waves in front of the jet combine by constructive interference. The result is a high-density compression that is called the* sound barrier*.*



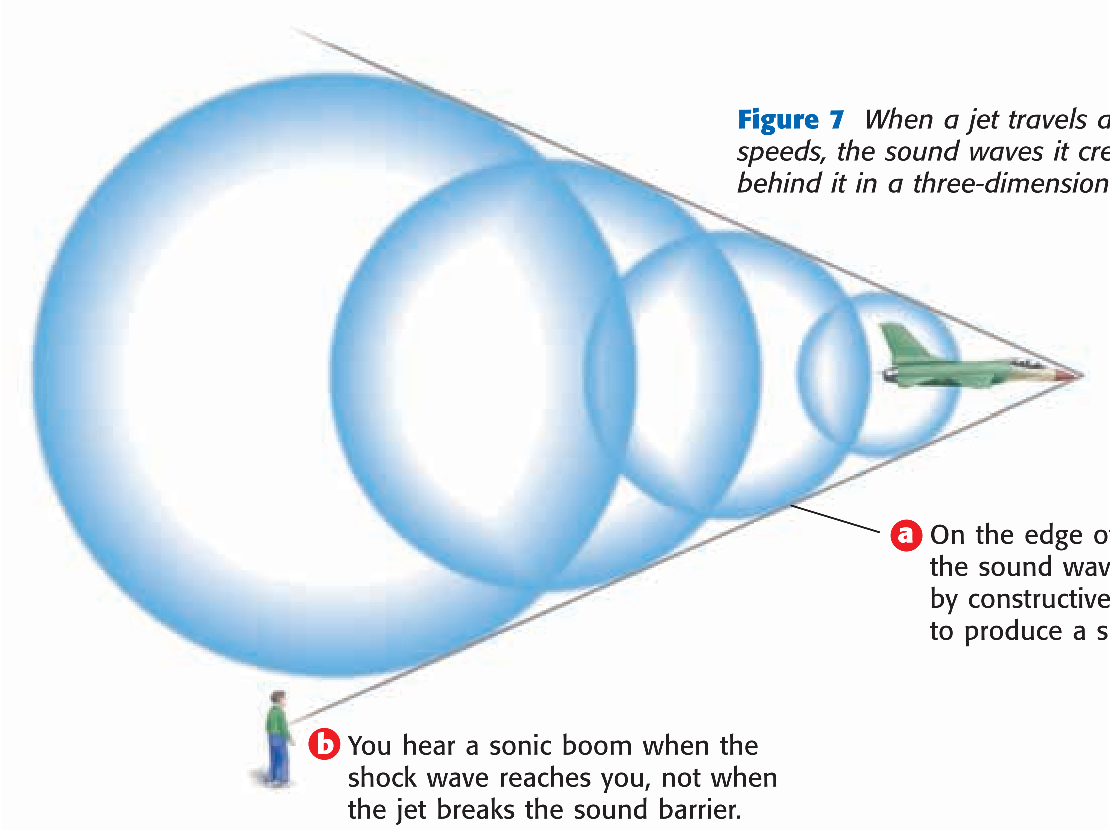
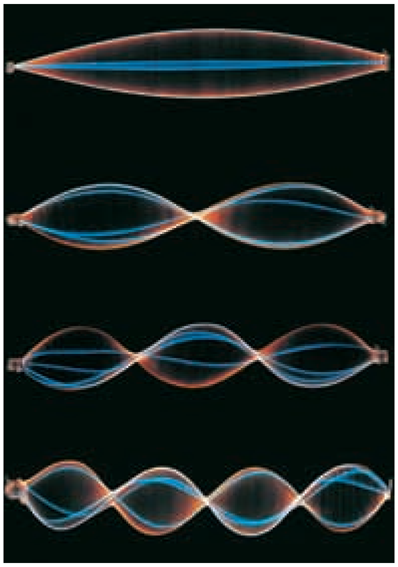


Figure 7 *When a jet travels at supersonic speeds, the sound waves it creates spread out behind it in a three-dimensional cone shape.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 8 **Resonant Frequencies of a Plucked String**



The lowest resonant frequency is called the *fundamental*.

Higher resonant frequencies are called *overtones*. The first overtone is twice the frequency of the fundamental.

The second overtone is 3 times the fundamental.

The third overtone is 4 times the fundamental.

standing wave a pattern of vibration that simulates a wave that is standing still

resonance a phenomenon that occurs when two objects naturally vibrate at the same frequency; the sound produced by one object causes the other object to vibrate

Interference and Standing Waves

When you play a guitar, you can make some pleasing sounds, and you might even play a tune. But have you ever watched a guitar string after you've plucked it? You may have noticed that the string vibrates as a standing wave. A **standing wave** is a pattern of vibration that looks like a wave that is standing still. Waves and reflected waves of the same frequency are going through the string. Where you see maximum amplitude, waves are interfering constructively. Where the string seems to be standing still, waves are interfering destructively.

Although you can see only one standing wave, which is at the *fundamental* frequency, the guitar string actually creates several standing waves of different frequencies at the same time. The frequencies at which standing waves are made are called *resonant frequencies*. Resonant frequencies and the relationships between them are shown in **Figure 8.**

Reading Check **What is a standing wave?**

Resonance

If you have a tuning fork, shown in **Figure 9,** that vibrates at one of the resonant frequencies of a guitar string, you can make the string make a sound without touching it. Strike the tuning fork, and hold it close to the string. The string will start to vibrate and produce a sound.

Using the vibrations of the tuning fork to make the string vibrate is an example of resonance. **Resonance** happens when an object vibrating at or near a resonant frequency of a second object causes the second object to vibrate.

Figure 9 *When struck, a tuning fork can make another object vibrate if they both have the same resonant frequency.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Resonance in Musical Instruments

Musical instruments use resonance to make sound. In wind instruments, vibrations are caused by blowing air into the mouthpiece. The vibrations make a sound, which is amplified when it forms a standing wave inside the instrument.

String instruments also resonate when they are played. An acoustic guitar, such as the one shown in **Figure 10,** has a hollow body. When the strings vibrate, sound waves enter the body of the guitar. Standing waves form inside the body of the guitar, and the sound is amplified.

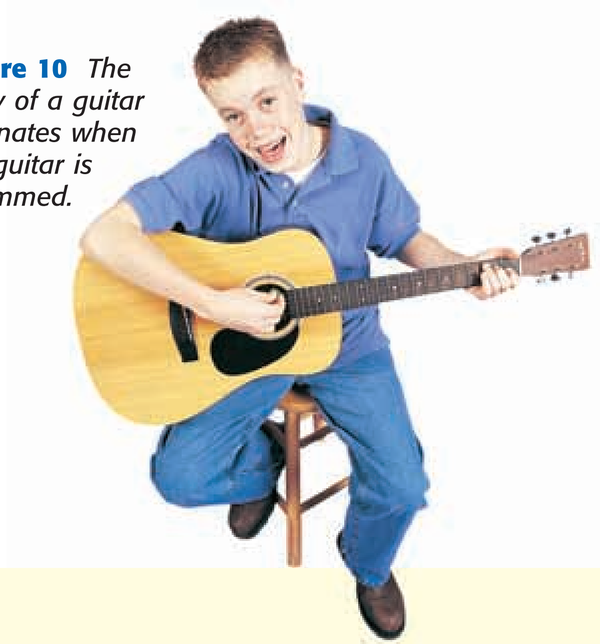


Figure 10 *The body of a guitar resonates when the guitar is strummed.*

SECTION Review

Summary

- Echoes are reflected sound waves.
- Some animals can use echolocation to find food or to navigate around objects.
- People use echolocation technology in many underwater applications.
- Ultrasonography uses sound reflection for medical applications.
- Sound barriers and shock waves are created by interference.
- Standing waves form at an object's resonant frequencies.
- Resonance happens when a vibrating object causes a second object to vibrate at one of its resonant frequencies.

Using Key Terms

1. Use the following terms in the same sentence: *echo* and *echolocation*.

Complete each of the following sentences by choosing the correct term from the word bank.

interference	standing wave
sonic boom	resonance

2. When you pluck a string on a musical instrument, a(n) _____ forms.
3. When a vibrating object causes a nearby object to vibrate, _____ results.

Understanding Key Ideas

4. What causes an echo?
   a. reflection
   b. resonance
   c. constructive interference
   d. destructive interference
5. Describe a place in which you would expect to hear echoes.
6. How do bats use echoes to find insects to eat?
7. Give one example each of constructive and destructive interference of sound waves.

Math Skills

8. Sound travels through air at 343 m/s at 20°C. A bat emits an ultrasonic squeak and hears the echo 0.05 s later. How far away was the object that reflected it? (Hint: Remember that the sound must travel *to* the object and *back to* the bat.)

Critical Thinking

9. **Applying Concepts** Your friend is playing a song on a piano. Whenever your friend hits a certain key, the lamp on top of the piano rattles. Explain why the lamp rattles.
10. **Making Comparisons** Compare sonar and ultrasonography in locating objects.

SCILINKS. Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Interactions of Sound Waves
SciLinks code: HSM0804

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 4

Sound Quality

Have you ever been told that the music you really like is just a lot of noise? If you have, you know that people can disagree about the difference between noise and music.

READING WARM-UP

Objectives

- Explain why different instruments have different sound qualities.
- Describe how each family of musical instruments produces sound.
- Explain how noise is different from music.

Terms to Learn

sound quality
noise

READING STRATEGY

Reading Organizer As you read this section, make a table comparing the way different instruments produce sound.

You might think of noise as sounds you don't like and music as sounds that are pleasant to hear. But the difference between music and noise does not depend on whether you like the sound. The difference has to do with sound quality.

What Is Sound Quality?

Imagine that the same note is played on a piano and on a violin. Could you tell the instruments apart without looking? The notes played have the same frequency. But you could probably tell them apart because the instruments make different sounds. The notes sound different because a single note on an instrument actually comes from several different pitches: the fundamental and several overtones. The result of the combination of these pitches is shown in **Figure 1.** The result of several pitches mixing together through interference is **sound quality.** Each instrument has a unique sound quality. **Figure 1** also shows how the sound quality differs when two instruments play the same note.

Figure 1 *Each instrument has a unique sound quality that results from the particular blend of overtones that it has.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Sound Quality of Instruments

The difference in sound quality among different instruments comes from their structural differences. All instruments produce sound by vibrating. But instruments vary in the part that vibrates and in the way that the vibrations are made. There are three main families of instruments: string instruments, wind instruments, and percussion instruments.

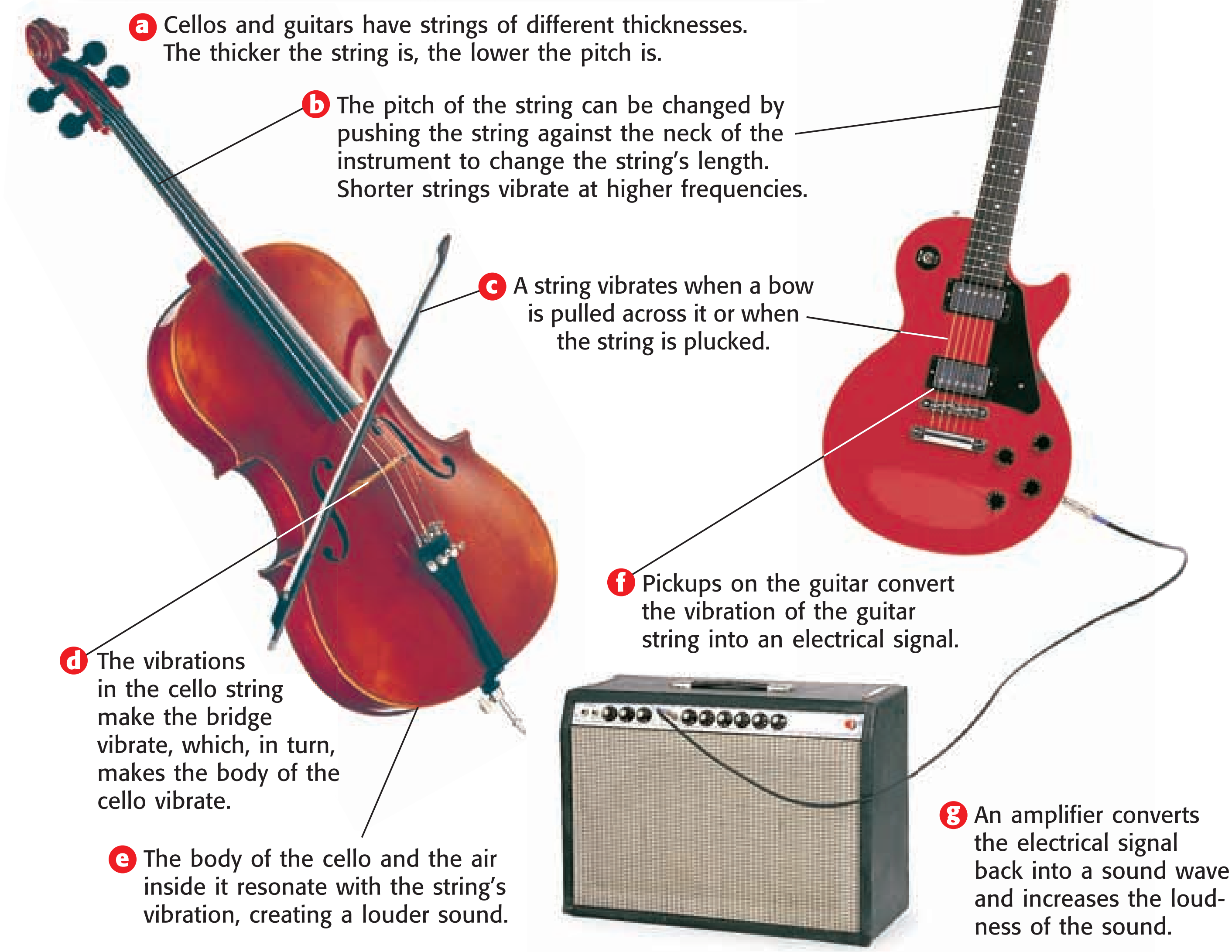
sound quality the result of the blending of several pitches through interference

Reading Check **How do musical instruments differ in how they produce sound?** (*See the Appendix for answers to Reading Checks.*)

String Instruments

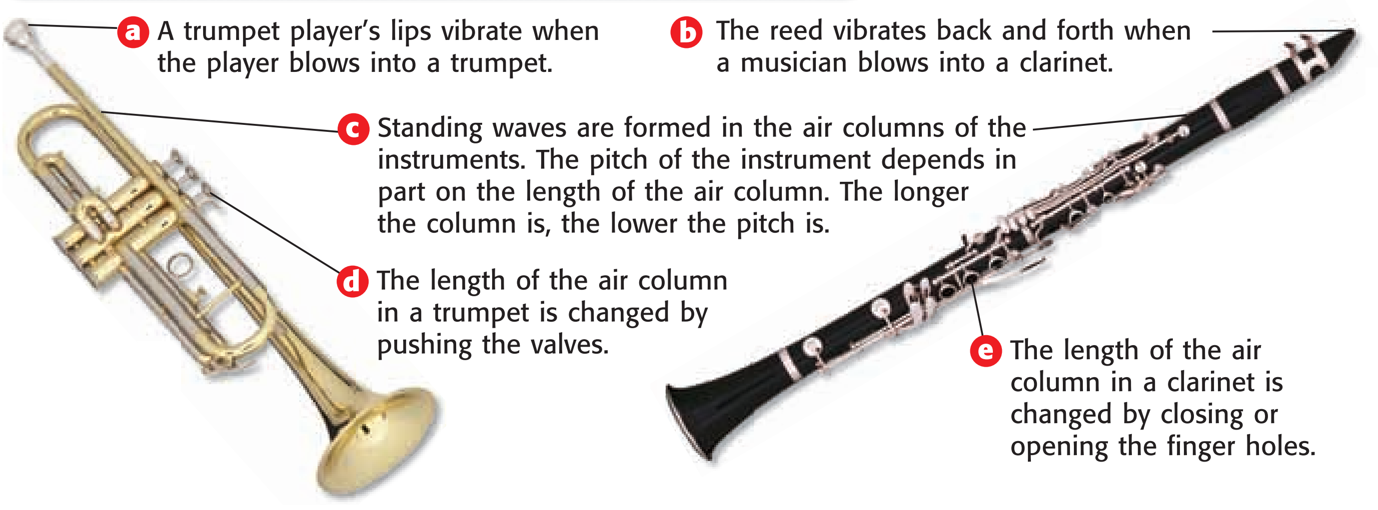
Violins, guitars, and banjos are examples of string instruments. They make sound when their strings vibrate after being plucked or bowed. **Figure 2** shows how two different string instruments produce sounds.

Figure 2 **String Instruments**



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 3 Wind Instruments



Wind Instruments

A wind instrument produces sound when a vibration is created at one end of its air column. The vibration causes standing waves inside the air column. Pitch is changed by changing the length of the air column. Wind instruments are sometimes divided into two groups—woodwinds and brass. Examples of woodwinds are saxophones, oboes, and recorders. French horns, trombones, and tubas are brass instruments. A brass instrument and a woodwind instrument are shown in **Figure 3.**

Percussion Instruments

Drums, bells, and cymbals are percussion instruments. They make sound when struck. Instruments of different sizes are used to get different pitches. Usually, the larger the instrument is, the lower the pitch is. The drums and cymbals in a trap set, shown in **Figure 4,** are percussion instruments.

Figure 4 Percussion Instruments

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Music or Noise?

Most of the sounds we hear are noises. The sound of a truck roaring down the highway, the slam of a door, and the jingle of keys falling to the floor are all noises. **Noise** can be described as any sound, especially a nonmusical sound, that is a random mix of frequencies (or pitches). **Figure 5** shows on an oscilloscope the difference between a musical sound and noise.

noise a sound that consists of a random mix of frequencies

Reading Check **What is the difference between music and noise?**

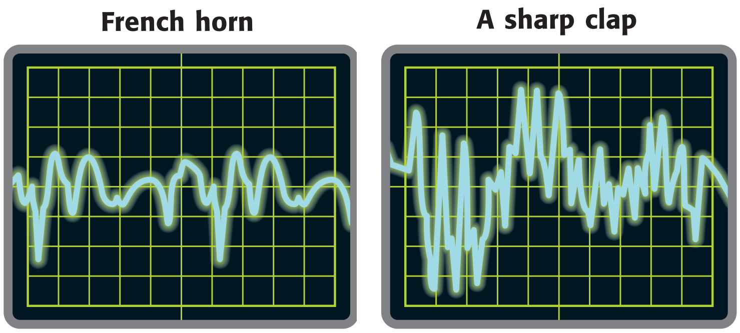


Figure 5 *A note from a French horn produces a sound wave with a repeating pattern, but noise from a clap produces complex sound waves with no regular pattern.*

SECTION Review

Summary

- Different instruments have different sound qualities.
- Sound quality results from the blending through interference of the fundamental and several overtones.
- The three families of instruments are string, wind, and percussion instruments.
- Noise is a sound consisting of a random mix of frequencies.

Using Key Terms

1. Use each of the following terms in a separate sentence: *sound quality* and *noise*.

Understanding Key Ideas

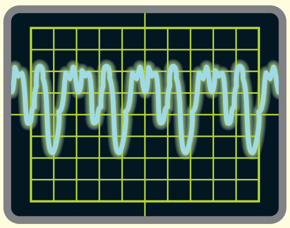
2. What interaction of sound waves determines sound quality?
   - a. reflection
   - b. diffraction
   - c. pitch
   - d. interference
3. Why do different instruments have different sound qualities?

Critical Thinking

4. **Making Comparisons** What do string instruments and wind instruments have in common in how they produce sound?
5. **Identifying Bias** Someone says that the music you are listening to is "just noise." Does the person mean that the music is a random mix of frequencies? Explain your answer.

Interpreting Graphics

6. Look at the oscilloscope screen below. Do you think the sound represented by the wave on the screen is noise or music? Explain your answer.



SCILINKS. Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Sound Quality
SciLinks code: HSM1427

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Using Scientific Methods

Skills Practice Lab

Easy Listening

OBJECTIVES

Measure your classmates' ability to detect different pitches at different distances.

Graph the average class data.

Form a conclusion about how easily pitches of different frequencies are heard at different distances.

MATERIALS

- eraser, hard rubber
- meterstick
- paper, graph
- tuning forks, different frequencies (4)

Pitch describes how low or high a sound is. A sound's pitch is related to its frequency—the number of waves per second. Frequency is measured in hertz (Hz), where 1 Hz equals 1 wave per second. Most humans can hear frequencies in the range from 20 Hz to 20,000 Hz. But not everyone detects all pitches equally well at all distances. In this activity, you will collect data to see how well you and your classmates hear different frequencies at different distances.

Ask a Question

1. Do most of the students in your classroom hear low-, mid-, or high-frequency sounds best?

Form a Hypothesis

2. Write a hypothesis that answers the question above. Explain your reasoning.

Test the Hypothesis

3. Choose one member of your group to be the sound maker. The others will be the listeners.
4. Copy the data table below onto another sheet of paper. Be sure to include a column for every listener in your group.

Data Collection Table

	Distance (m)			
Frequency	Listener 1	Listener 2	Listener 3	Average
1 (_____Hz)				
2 (_____Hz)				
3 (_____Hz)				
4 (_____Hz)				

DO NOT WRITE IN BOOK

5. The sound maker will choose one of the tuning forks, and record the frequency of the tuning fork in the data table.
6. The listeners should stand 1 m from the sound maker with their backs turned.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

7 The sound maker will create a sound by striking the tip of the tuning fork gently with the eraser.

8 Listeners who hear the sound should take one step away from the sound maker. The listeners who do not hear the sound should stay where they are.

9 Repeat steps 7 and 8 until none of the listeners can hear the sound or the listeners reach the edge of the room.

10 Using the meterstick, the sound maker should measure the distance from his or her position to each of the listeners. All group members should record this data.

11 Repeat steps 5 through 10 with a tuning fork of a different frequency.

12 Continue until all four tuning forks have been tested.

Analyze the Results

1 **Organizing Data** Calculate the average distance for each frequency. Share your group's data with the rest of the class to make a data table for the whole class.

2 **Analyzing Data** Calculate the average distance for each frequency for the class.

3 **Constructing Graphs** Make a graph of the class results, plotting average distance (y-axis) versus frequency (x-axis).

Draw Conclusions

4 **Drawing Conclusions** Was everyone in the class able to hear all of frequencies equally? (Hint: Was the average distance for each frequency the same?)

5 **Evaluating Data** If the answer to question 4 is no, which frequency had the longest average distance? Which frequency had the shortest final distance?

6 **Analyzing Graphs** Based on your graph, do your results support your hypothesis? Explain your answer.

7 **Evaluating Methods** Do you think your class sample is large enough to confirm your hypothesis for all people of all ages? Explain your answer.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Chapter Review

USING KEY TERMS

Complete each of the following sentences by choosing the correct term from the word bank.

loudness
echoes
pitch
noise
sound quality

1. The _____ of a sound wave depends on its amplitude.

2. Reflected sound waves are called _____.

3. Two different instruments playing the same note sound different because of _____.

UNDERSTANDING KEY IDEAS

Multiple Choice

4. If a fire engine is traveling toward you, the Doppler effect will cause the siren to sound
   - **a.** higher.
   - **b.** lower.
   - **c.** louder.
   - **d.** softer.

5. Sound travels fastest through
   - **a.** a vacuum.
   - **b.** sea water.
   - **c.** air.
   - **d.** glass.

6. If two sound waves interfere constructively, you will hear
   - **a.** a high-pitched sound.
   - **b.** a softer sound.
   - **c.** a louder sound.
   - **d.** no change in sound.

7. You will hear a sonic boom when
   - **a.** an object breaks the sound barrier.
   - **b.** an object travels at supersonic speeds.
   - **c.** a shock wave reaches your ears.
   - **d.** the speed of sound is 290 m/s.

8. Resonance can happen when an object vibrates at another object's
   - **a.** resonant frequency.
   - **b.** fundamental frequency.
   - **c.** second overtone frequency.
   - **d.** All of the above

9. A technological device that can be used to see sound waves is a(n)
   - **a.** sonar.
   - **b.** oscilloscope.
   - **c.** ultrasound.
   - **d.** amplifier.

Short Answer

10. Describe how the Doppler effect helps a beluga whale determine whether a fish is moving away from it or toward it.

11. How do vibrations cause sound waves?

12. Briefly describe what happens in the different parts of the ear.

Math Skills

13. A submarine that is not moving sends out a sonar sound wave traveling 1,500 m/s, which reflects off a boat back to the submarine. The sonar crew detects the reflected wave 6 s after it was sent out. How far away is the boat from the submarine?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

CRITICAL THINKING

14. **Concept Mapping** Use the following terms to create a concept map: *sound waves, pitch, loudness, decibels, frequency, amplitude, oscilloscope, hertz,* and *interference.*

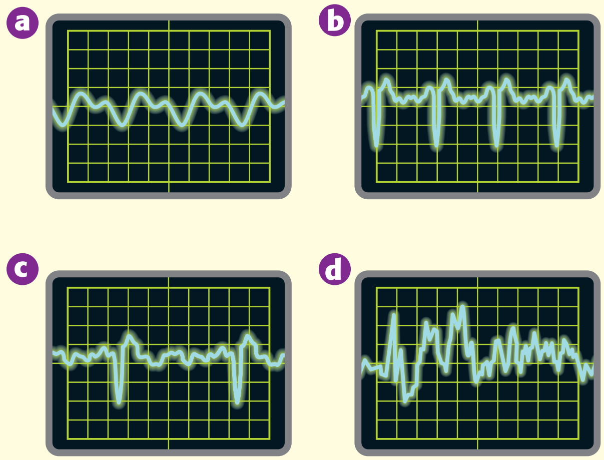
15. **Analyzing Processes** An *anechoic chamber* is a room where there is almost no reflection of sound waves. Anechoic chambers are often used to test sound equipment, such as stereos. The walls of such chambers are usually covered with foam triangles. Explain why this design eliminates echoes in the room.

16. **Applying Concepts** Would the pilot of an airplane breaking the sound barrier hear a sonic boom? Explain why or why not.

17. **Forming Hypotheses** After working in a factory for a month, a man you know complains about a ringing in his ears. What might be wrong with him? What do you think may have caused his problem? What can you suggest to him to prevent further hearing loss?

INTERPRETING GRAPHICS

Use the oscilloscope screens below to answer the questions that follow:



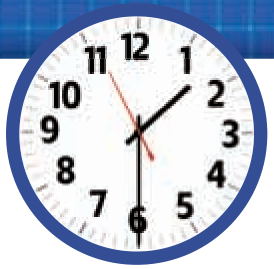
18. Which sound is noise?

19. Which represents the softest sound?

20. Which represents the sound with the lowest pitch?

21. Which two sounds were produced by the same instrument?

Copyright © by Holt, Rinehart and Winston. All rights reserved.



Standardized Test Preparation

READING

Read each of the passages below. Then, answer the questions that follow each passage.

Passage 1 Centuries ago, Marco Polo wrote about the booming sand dunes of the Asian desert. He wrote that the booming sands filled the air with the sounds of music, drums, and weapons of war. Booming sands are most often found in the middle of large deserts. They have been discovered all over the world, including the United States. Booming sands make loud, low-pitched sounds when the top layers of sand slip over the layers below, producing vibrations. The sounds have been compared to foghorns, cannon fire, and moaning. The sounds can last from a few seconds to 15 min and can be heard more than 10 km away!

1. Which is a fact in this passage?

A Marco Polo loved traveling.
B Booming sands always sound like moaning people.
C Booming sands are the most interesting thing in Asia.
D Some booming sands are found in the United States.

2. Which of the following phrases **best** describes booming sands?

F found in Asia
G noisy
H slippery
I discovered by Marco Polo

3. What causes booming sands?

A vibrations caused by top layers of sand slipping over layers below
B battles in the desert
C animals that live beneath sand dunes
D There is not enough information to determine the answer.

Passage 2 People who work in the field of architectural acoustics are concerned with controlling sound that travels in a closed space. Their goal is to make rooms and buildings quiet yet suitable for people to enjoy talking and listening to music. One major factor that affects the acoustical quality of a room is the way the room reflects sound waves. Sound waves bounce off surfaces such as doors, ceilings, and walls. Using materials that absorb sound reduces the reflection of sound waves. Materials that have small pockets of air that can trap the sound vibrations and keep them from reflecting are the most sound absorbent. Sound-absorbing floor and ceiling tiles, curtains, and upholstered furniture all help to control the reflection of sound waves.

1. The field of architectural acoustics is concerned with which of the following?

A making buildings earthquake safe
B controlling sound in closed spaces
C designing sound-absorbing materials
D making buildings as quiet as possible

2. Which of the following is a major factor in the acoustical quality of a room?

F the size of the room
G the furnishings in the room
H the walls of the room
I the noise level in the room

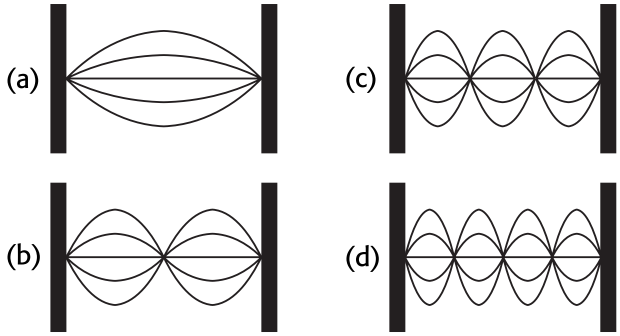
3. Which of the following materials is **most** likely to absorb sounds the best?

A materials that have small pockets of air
B surfaces such as doors, ceilings, and walls
C materials that keep the room as quiet as possible
D furniture that is made of wood

Copyright © by Holt, Rinehart and Winston. All rights reserved.

INTERPRETING GRAPHICS

Use the pictures of standing waves below to answer the questions that follow.



1. Which of the standing waves has the lowest frequency?
   - **A** a
   - **B** b
   - **C** c
   - **D** d

2. Which of the standing waves has the highest frequency?
   - **F** a
   - **G** b
   - **H** c
   - **I** d

3. Which of the standing waves represents the first overtone?
   - **A** a
   - **B** b
   - **C** c
   - **D** d

4. In which of the following pairs of standing waves is the frequency of the second wave twice the frequency of the first?
   - **F** a, b
   - **G** a, c
   - **H** b, c
   - **I** c, d

MATH

Read each question below, and choose the best answer.

1. The speed of sound in copper is 3,560 m/s. Which is another way to express this measure?
   - **A** 356×10^2 m/s
   - **B** 0.356×10^3 m/s
   - **C** 3.56×10^3 m/s
   - **D** 3.56×10^4 m/s

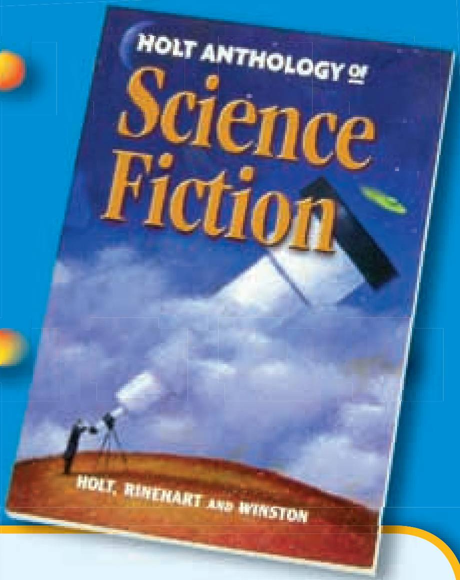
2. The speed of sound in sea water is 1,522 m/s. How far can a sound wave travel underwater in 10 s?
   - **F** 152.2 m
   - **G** 1,522 m
   - **H** 15,220 m
   - **I** 152,220 m

3. Claire likes to go swimming after work. She warms up for 120 s before she begins swimming, and it takes her an average of 55 s to swim one lap. Which equation could be used to find *w*, the number of seconds it takes for Claire to warm up and swim 15 laps?
   - **A** $w = (15 \times 120) + 55$
   - **B** $w = (15 \times 55) + 120$
   - **C** $w = 120 + 55 + 15$
   - **D** $w = (15 \times 55) \times 120$

4. The Vasquez family went bowling. They rented 6 pairs of shoes for $3 a pair and bowled for 2 h at a rate of $8.80/h. Which is the best estimate of the total cost of the shoes and bowling?
   - **F** $24
   - **G** $30
   - **H** $36
   - **I** $45

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Science in Action



Scientific Discoveries

Jurassic Bark

Imagine you suddenly hear a loud honking sound, such as a trombone or a tuba. "Must be band tryouts," you think. You turn to find the noise and find yourself face to face with a 10 m long, 2,800 kg dinosaur with a huge tubular crest on its snout. Do you run? No—your musical friend, *Parasaurolophus,* is a vegetarian. In 1995, an almost-complete fossil skull of an adult *Parasaurolophus* was found in New Mexico. Scientists studied the noise-making qualities of *Parasaurolophus*'s crest and found that it contained many internal tubes and chambers.

Math ACTIVITY

Imagine that a standing wave with a frequency of 80 Hz is made inside the crest of a *Parasaurolophus*. What would be the frequency of the first overtone of this standing wave? the second? the third?

Science Fiction

"Ear" by Jane Yolen

Jily and her friends, Sanya and Feeny, live in a time not too far in the future. It is a time when everyone's hearing is damaged. People communicate using sign language—unless they put on their Ear. Then, the whole world is filled with sounds.

Jily and her friends visit a club called The Low Down. It is too quiet for Jily's tastes, and she wants to leave. But Sanya is dancing by herself, even though there is no music. When Jily finds Feeny, they notice some Earless kids their own age. Earless people never go to clubs, and Jily finds their presence offensive. But Feeny is intrigued.

Everyone is given an Ear at the age of 12 but has to give it up at the age of 30. Why would these kids want to go out without their Ears before the age of 30? Jily thinks the idea is ridiculous and doesn't stick around to find out the answer to such a question. But it is an answer that will change her life by the end of the next day.

Language Arts ACTIVITY

WRITING SKILL Read "Ear," by Jane Yolen, in the *Holt Anthology of Science Fiction.* Write a one-page report that discusses how the story made you think about the importance of hearing in your everyday life.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Adam Dudley

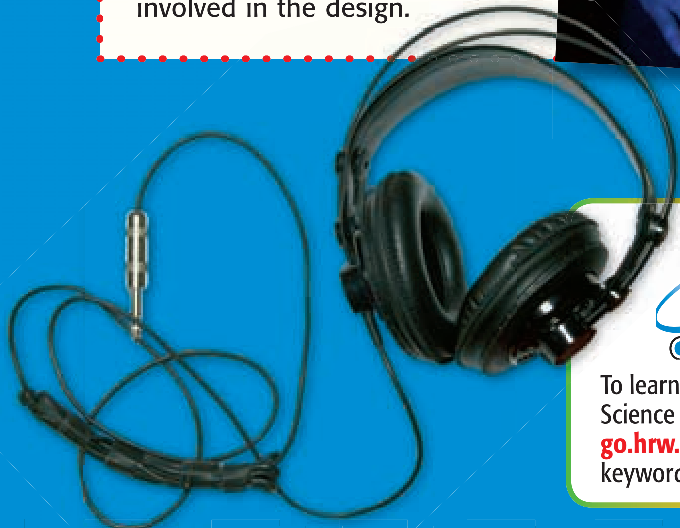
Sound Engineer Adam Dudley uses the science of sound waves every day at his job. He is the audio supervisor for the Performing Arts Center of the University of Texas at Austin. Dudley oversees sound design and technical support for campus performance spaces, including an auditorium that seats over 3,000 people.

To stage a successful concert, Dudley takes many factors into account. The size and shape of the room help determine how many speakers to use and where to place them. It is a challenge to make sure people seated in the back row can hear well enough and also to make sure that the people up front aren't going deaf from the high volume.

Adam Dudley loves his job—he enjoys working with people and technology and prefers not to wear a coat and tie. Although he is invisible to the audience, his work backstage is as crucial as the musicians and actors on stage to the success of the events.

Social Studies ACTIVITY

Use the Internet to research concert halls that were designed before the use of electrical amplification. Make a model of one and present it to the class. Use a computer generated presentation to help explain the acoustical factors involved in the design.



go.hrw.com

To learn more about these Science in Action topics, visit go.hrw.com and type in the keyword **HP5SNDF.**

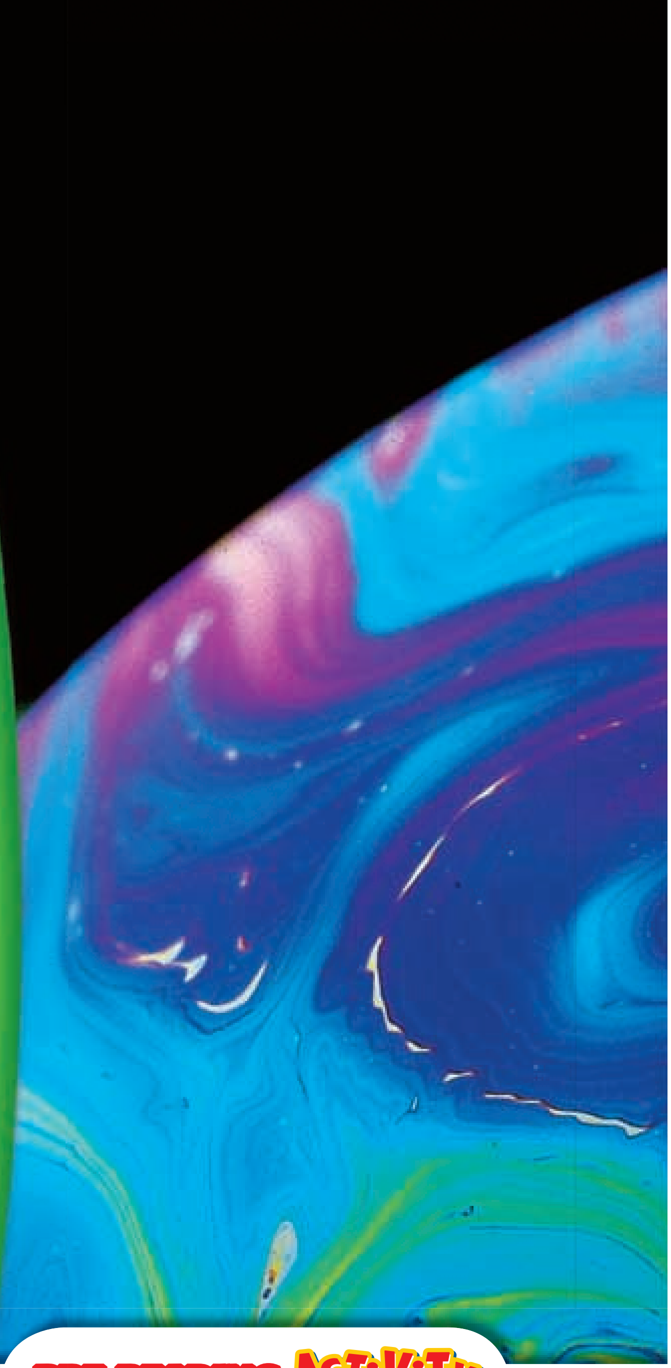
Current Science

Check out Current Science® articles related to this chapter by visiting go.hrw.com. Just type in the keyword HP5CS21.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

17

The Nature of Light

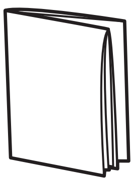


About the PHOTO

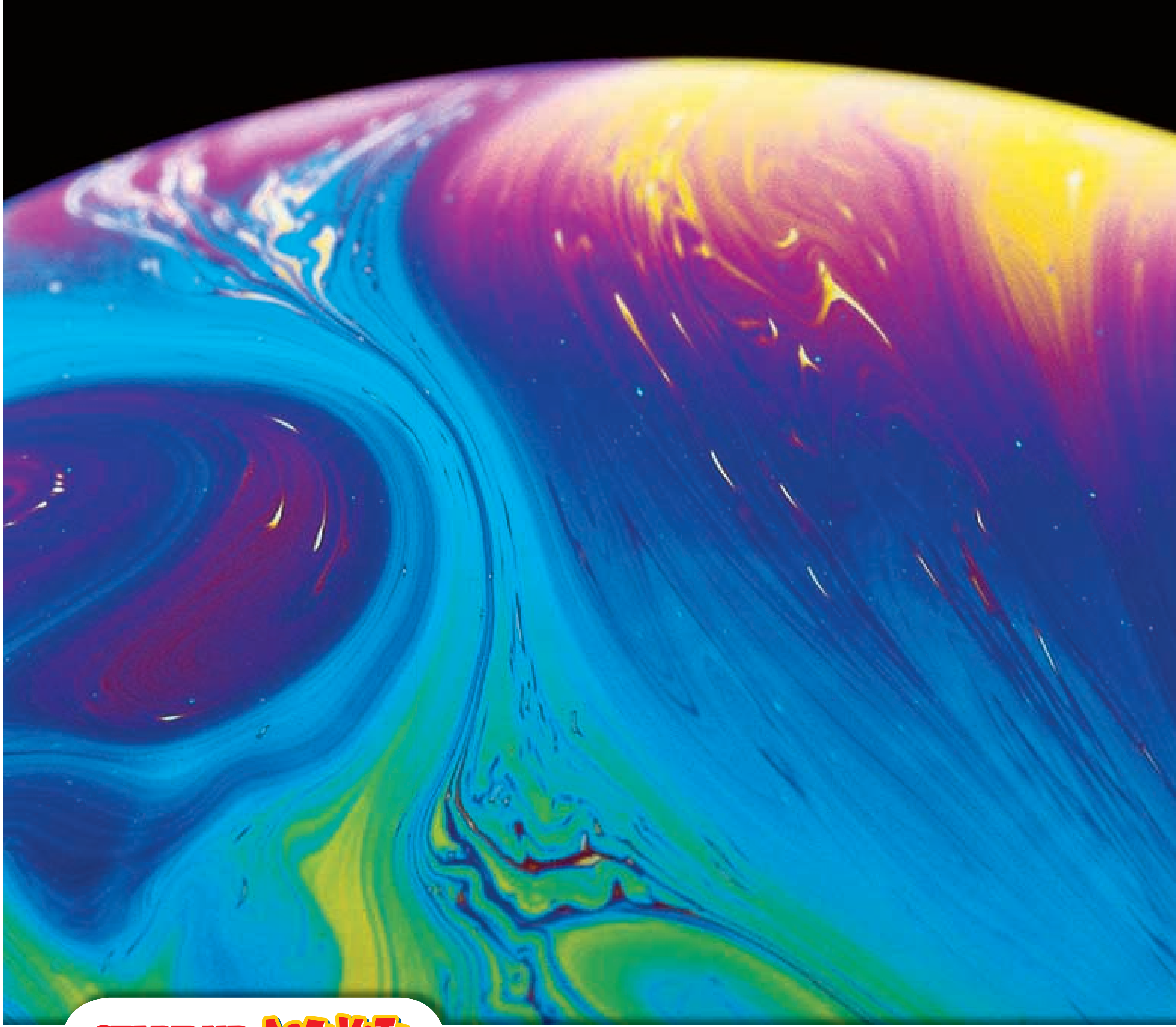
What kind of alien life lives on this planet? Actually, this isn't a planet at all. It's an ordinary soap bubble! The brightly colored swirls on this bubble are reflections of light. Light waves combine through interference so that you see different colors on this soap bubble.

PRE-READING ACTIVITY

FOLDNOTES **Booklet** Before you read the chapter, create the FoldNote entitled "Booklet" described in the **Study Skills** section of the Appendix. Label each page of the booklet with a main idea from the chapter. As you read the chapter, write what you learn about each main idea on the appropriate page of the booklet.



Copyright © by Holt, Rinehart and Winston. All rights reserved.



START-UP ACTIVITY

Colors of Light

Is white light really white? In this activity, you will use a spectroscope to answer that question.

Procedure

1. Your teacher will give you a **spectroscope** or instructions for making one.
2. Turn on an **incandescent light bulb.** Look at the light bulb through your spectroscope. Write a description of what you see.
3. Repeat step 2, looking at a **fluorescent light.** Again, describe what you see.

Analysis

1. Compare what you saw with the incandescent light bulb with what you saw with the fluorescent light bulb.
2. Both kinds of bulbs produce white light. What did you learn about white light by using the spectroscope?
3. Light from a flame is yellowish but is similar to white light. What do you think you would see if you used a spectroscope to look at light from a flame?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 1

What Is Light?

You can see light. It's everywhere! Light comes from the sun and from other sources, such as light bulbs. But what exactly is light?

READING WARM-UP

Objectives

- Describe light as an electromagnetic wave.
- Calculate distances traveled by light by using the speed of light.
- Explain why light from the sun is important.

Terms to Learn

electromagnetic wave
radiation

READING STRATEGY

Brainstorming The key idea of this section is light. Brainstorm words and phrases related to light.

Scientists are still studying light to learn more about it. A lot has already been discovered about light, as you will soon find out. Read on, and be enlightened!

Light: An Electromagnetic Wave

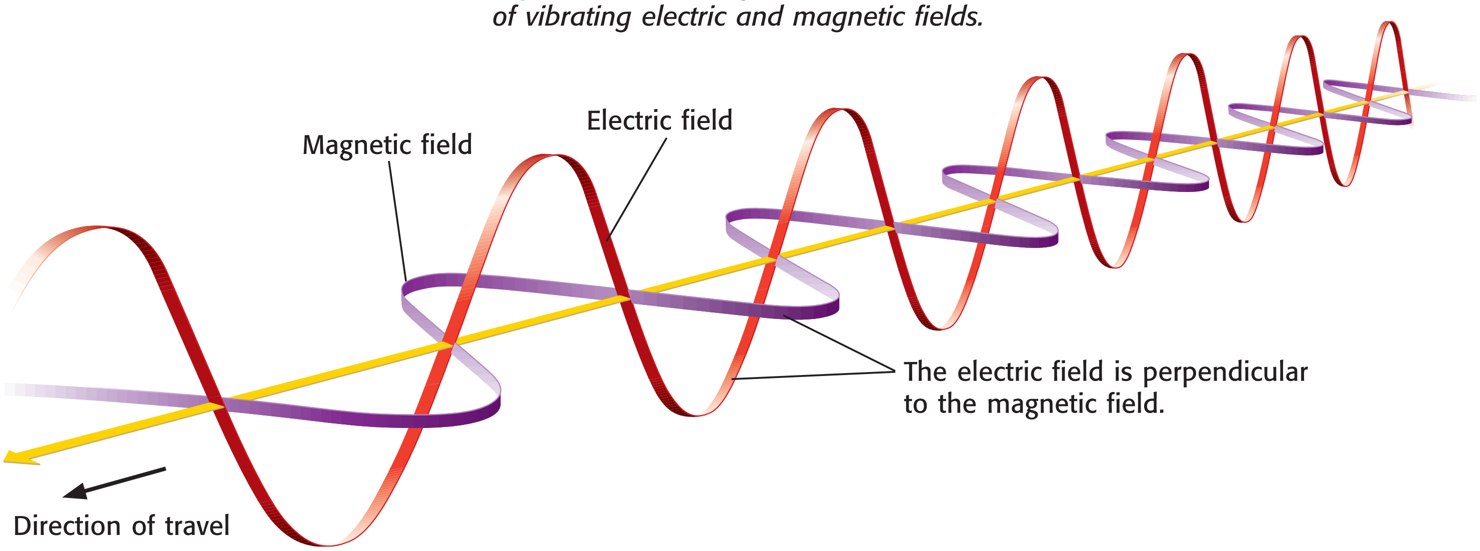
Light is a type of energy that travels as a wave. But light is different from other kinds of waves. Other kinds of waves, like sound waves and water waves, must travel through matter. Light does not require matter through which to travel. Light is an electromagnetic wave (EM wave). An **electromagnetic wave** is a wave that can travel through empty space or matter and consists of changing electric and magnetic fields.

Fields exist around certain objects and can exert a force on another object without touching that object. For example, Earth is a source of a gravitational field. This field pulls you and all things toward Earth. But keep in mind that this field, like all fields, is not made of matter.

Figure 1 shows a diagram of an electromagnetic wave. Notice that the electric and magnetic fields are at right angles—or are *perpendicular*—to each other. These fields are also perpendicular to the direction of the wave motion.

electromagnetic wave a wave that consists of electric and magnetic fields that vibrate at right angles to each other

Figure 1 *Electromagnetic waves are made of vibrating electric and magnetic fields.*



Copyright © by Holt, Rinehart and Winston. All rights reserved.

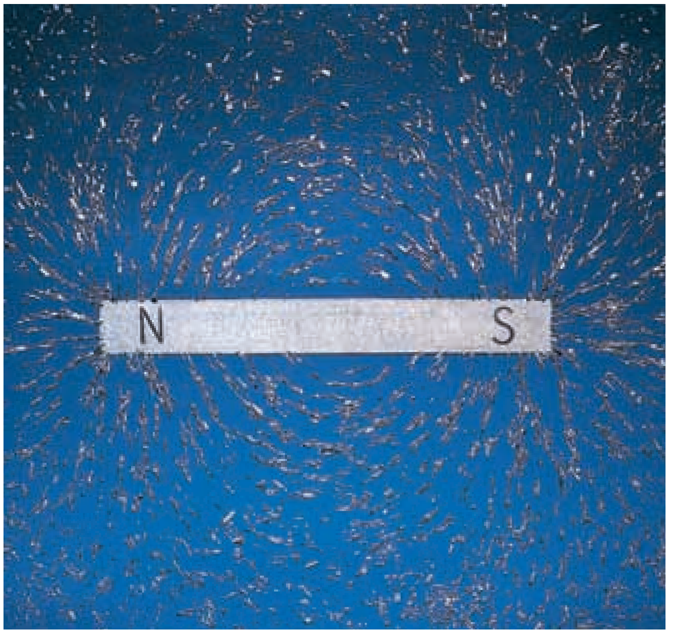


Figure 2 *The hair on the girl's head stands up because of an electric field and the iron filings form arcs around the magnet because of a magnetic field.*

Electric and Magnetic Fields

Electromagnetic waves are changing electric and magnetic fields. But what are electric and magnetic fields? An *electric field* surrounds every charged object. The electric field around a charged object pulls oppositely charged objects toward it and repels like-charged objects. You can see the effect of electric fields whenever you see objects stuck together by static electricity. **Figure 2** shows another effect of an electric field.

A *magnetic field* surrounds every magnet. Because of magnetic fields, paper clips and iron filings are pulled toward magnets. You can feel the effect of magnetic fields when you hold two magnets close together. The iron filings around the magnet in **Figure 2** form arcs in the presence of the magnet's magnetic field.

Reading Check **Where can electric fields be found?** (*See the Appendix for answers to Reading Checks.*)

How EM Waves Are Produced

An EM wave can be produced by the vibration of an electrically charged particle. When the particle vibrates, or moves back and forth, the electric field around it also vibrates. When the electric field starts vibrating, a vibrating magnetic field is created. The vibration of an electric field and a magnetic field together produces an EM wave that carries energy released by the original vibration of the particle. The transfer of energy as electromagnetic waves is called **radiation.**

CONNECTION TO Social Studies

WRITING SKILL **The Particle Model of Light**
Thinking of light as being an electromagnetic wave can explain many properties of light. But some properties of light can be explained only by using a particle model of light. In the particle model of light, light is thought of as a stream of particles called *photons*. Research the history of the particle model of light. Write a one-page paper on what you learn.

radiation transfer of energy as electromagnetic waves

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 3 *Thunder and lightning are produced at the same time. But you usually see lightning before you hear thunder, because light travels much faster than sound.*

The Speed of Light

Scientists have yet to discover anything that travels faster than light. In the near vacuum of space, the speed of light is about 300,000,000 m/s, or 300,000 km/s. Light travels slightly slower in air, glass, and other types of matter. (Keep in mind that even though electromagnetic waves do not need to travel through matter, they can travel through many substances.)

Believe it or not, light can travel about 880,000 times faster than sound! This fact explains the phenomenon described in **Figure 3.** If you could run at the speed of light, you could travel around Earth 7.5 times in 1 s.

Reading Check **How does the speed of light compare with the speed of sound?**

Math Focus

How Fast Is Light? The distance from Earth to the moon is 384,000 km. Calculate the time it takes for light to travel that distance.

Step 1: Write the equation for speed.

$$speed = \frac{distance}{time}$$

Step 2: Rearrange the equation by multiplying by time and dividing by speed.

$$time = \frac{distance}{speed}$$

Step 3: Replace *distance* and *speed* with the values given in the problem, and solve.

$$time = \frac{384{,}000 \text{ km}}{300{,}000 \text{ km/s}}$$

$$time = 1.28 \text{ s}$$

Now It's Your Turn

1. The distance from the sun to Venus is 108,000,000 km. Calculate the time it takes for light to travel that distance.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Light from the Sun

Even though light travels quickly, it takes about 8.3 min for light to travel from the sun to Earth. It takes this much time because Earth is 150,000,000 km away from the sun.

The EM waves from the sun are the major source of energy on Earth. For example, plants use photosynthesis to store energy from the sun. And animals use and store energy by eating plants or by eating other animals that eat plants. Even fossil fuels, such as coal and oil, store energy from the sun. Fossil fuels are formed from the remains of plants and animals that lived millions of years ago.

Although Earth receives a large amount of energy from the sun, only a very small part of the total energy given off by the sun reaches Earth. Look at **Figure 4.** The sun gives off energy as EM waves in all directions. Most of this energy travels away in space.

Figure 4 *Only a small amount of the sun's energy reaches the planets in the solar system.*

SECTION Review

Summary

- Light is an electromagnetic (EM) wave. An EM wave is a wave that consists of changing electric and magnetic fields. EM waves require no matter through which to travel.
- EM waves can be produced by the vibration of charged particles.
- The speed of light in a vacuum is about 300,000,000 m/s.
- EM waves from the sun are the major source of energy for Earth.

Using Key Terms

1. Use the following terms in the same sentence: *electromagnetic wave* and *radiation*.

Understanding Key Ideas

2. Electromagnetic waves are different from other types of waves because they can travel through
   a. air. **c.** space.
   b. glass. **d.** steel.
3. Describe light in terms of electromagnetic waves.
4. Why is light from the sun important?
5. How can electromagnetic waves be produced?

Math Skills

6. The distance from the sun to Jupiter is 778,000,000 km. How long does it take for light from the sun to reach Jupiter?

Critical Thinking

7. **Making Inferences** Why is it important that EM waves can travel through empty space?
8. **Making Comparisons** How does the amount of energy produced by the sun compare with the amount of energy that reaches Earth from the sun?
9. **Applying Concepts** Explain why the energy produced by burning wood in a campfire is energy from the sun.

SCILINKS®
NSTA
Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Light Energy
SciLinks code: HSM0880

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 2

Interactions of Light Waves

Have you ever seen a cat's eyes glow in the dark when light shines on them? Cats have a special layer of cells in the back of their eyes that reflects light.

READING WARM-UP

Objectives

- Describe how reflection allows you to see things.
- Describe absorption and scattering.
- Explain how refraction can create optical illusions and separate white light into colors.
- Explain the relationship between diffraction and wavelength.
- Compare constructive and destructive interference of light.

Terms to Learn

reflection	refraction
absorption	diffraction
scattering	interference

READING STRATEGY

Reading Organizer As you read this section, make a concept map by using the terms above.

This layer helps the cat see better by giving the eyes another chance to detect the light. Reflection is one interaction of electromagnetic waves. In this section, you will learn about wave interactions by using visible light. *Visible light* is the name given to the electromagnetic waves that humans can see.

Reflection

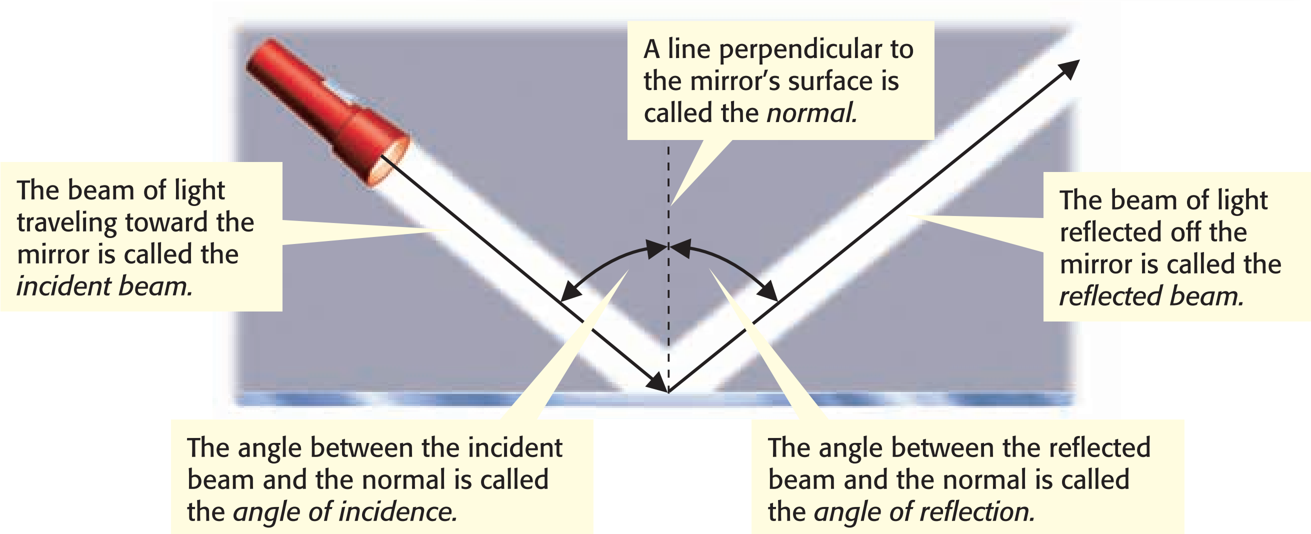
Reflection happens when light waves bounce off an object. Light reflects off objects all around you. When you look in a mirror, you are seeing light that has been reflected twice—first from you and then from the mirror. If light is reflecting off everything around you, why can't you see your image on a wall? To answer this question, you must learn the law of reflection.

The Law of Reflection

Light reflects off surfaces the same way that a ball bounces off the ground. If you throw the ball straight down against a smooth surface, it will bounce straight up. If you bounce it at an angle, it will bounce away at an angle. The *law of reflection* states that the angle of incidence is equal to the angle of reflection. *Incidence* is the arrival of a beam of light at a surface. **Figure 1** shows this law.

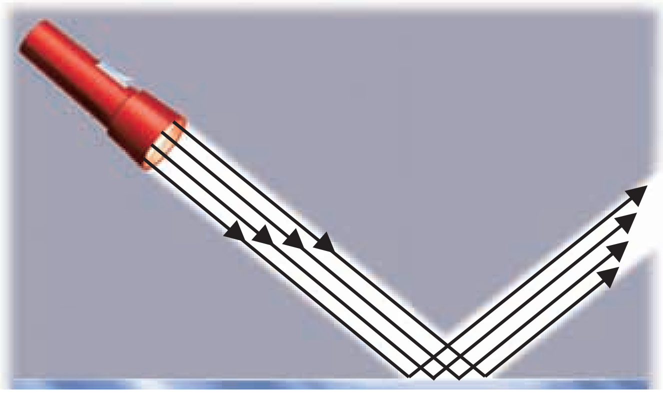
Reading Check **What is the law of reflection?** (*See the Appendix for answers to Reading Checks.*)

Figure 1 **The Law of Reflection**

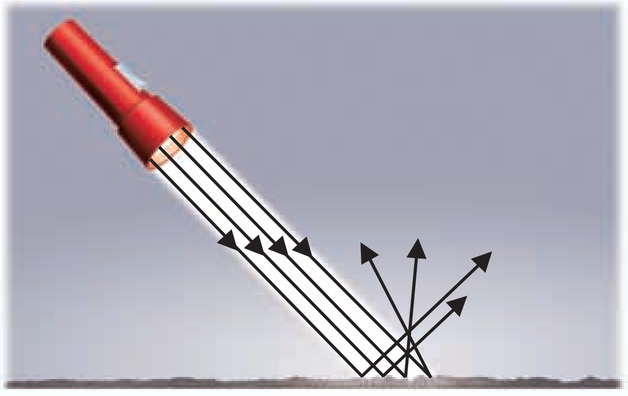


Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 2 **Regular Reflection Vs. Diffuse Reflection**



Regular reflection occurs when light beams are reflected at the same angle. When your eye detects the reflected beams, you can see a reflection on the surface.



Diffuse reflection occurs when light beams reflect at many different angles. You can't see a reflection because not all of the reflected light is directed toward your eyes.

Types of Reflection

So, why can you see your image in a mirror but not in a wall? The answer has to do with the differences between the two surfaces. A mirror's surface is very smooth. Thus, light beams reflect off all points of the mirror at the same angle. This kind of reflection is called *regular reflection*. A wall's surface is slightly rough. Light beams will hit the wall's surface and reflect at many different angles. This kind of reflection is called *diffuse reflection*. **Figure 2** shows the difference between the two kinds of reflection.

reflection the bouncing back of a ray of light, sound, or heat when the ray hits a surface that it does not go through

Light Source or Reflection?

If you look at a TV set in a bright room, you see the cabinet around the TV and the image on the screen. But if you look at the same TV in the dark, you see only the image on the screen. The difference is that the screen is a light source, but the cabinet around the TV is not.

You can see a light source even in the dark because its light passes directly into your eyes. The tail of the firefly in **Figure 3** is a light source. Flames, light bulbs, and the sun are also light sources. Objects that produce visible light are called *luminous* (LOO muh nuhs).

Most things around you are not light sources. But you can still see them because light from light sources reflects off the objects and then travels to your eyes. A visible object that is not a light source is *illuminated*.

Figure 3 *You can see the tail of this firefly because it is luminous. But you see its body because it is illuminated.*

Reading Check **List four different light sources.**

Copyright © by Holt, Rinehart and Winston. All rights reserved.

CONNECTION TO
Astronomy

Moonlight? Sometimes, the moon shines so brightly that you might think there is a lot of "moonlight." But did you know that moonlight is actually sunlight? The moon does not give off light. You can see the moon because it is illuminated by light from the sun. You see different phases of the moon because light from the sun shines only on the part of the moon that faces the sun. Make a poster that shows the different phases of the moon.

ACTIVITY

Absorption and Scattering

absorption in optics, the transfer of light energy to particles of matter

scattering an interaction of light with matter that causes light to change its energy, direction of motion, or both

Have you noticed that when you use a flashlight, the light shining on things closer to you appears brighter than the light shining on things farther away? The light is less bright the farther it travels from the flashlight. The light is weaker partly because the beam spreads out and partly because of absorption and scattering.

Absorption of Light

The transfer of energy carried by light waves to particles of matter is called **absorption.** When a beam of light shines through the air, particles in the air absorb some of the energy from the light. As a result, the beam of light becomes dim. The farther the light travels from its source, the more it is absorbed by particles, and the dimmer it becomes.

Figure 4 *A beam of light becomes dimmer partly because of scattering.*

Scattering of Light

Scattering is an interaction of light with matter that causes light to change direction. Light scatters in all directions after colliding with particles of matter. Light from the ship shown in **Figure 4** is scattered out of the beam by air particles. This scattered light allows you to see things that are outside the beam. But, because light is scattered out of the beam, the beam becomes dimmer.

Scattering makes the sky blue. Light with shorter wavelengths is scattered more than light with longer wavelengths. Sunlight is made up of many different colors of light, but blue light (which has a very short wavelength) is scattered more than any other color. So, when you look at the sky, you see a background of blue light.

Reading Check **Why can you see things outside a beam of light?**

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Refraction

Imagine that you and a friend are at a lake. Your friend wades into the water. You look at her, and her feet appear to have separated from her legs! What has happened? You know her feet did not fall off, so how can you explain what you see? The answer has to do with refraction.

Refraction and Material

Refraction is the bending of a wave as it passes at an angle from one substance, or material, to another. **Figure 5** shows a beam of light refracting twice. Refraction of light waves occurs because the speed of light varies depending on the material through which the waves are traveling. In a vacuum, light travels at 300,000 km/s, but it travels more slowly through matter. When a wave enters a new material at an angle, the part of the wave that enters first begins traveling at a different speed from that of the rest of the wave.

refraction the bending of a wave as the wave passes between two substances in which the speed of the wave differs

Refraction and Lenses

A *lens* is a transparent object that refracts light to form an image. Lenses are used in cameras, telescopes, microscopes, and eyeglasses. Two kinds of lenses are convex lenses and concave lenses. *Convex lenses* are thicker in the middle than at the edges. When light beams pass through a convex lens, the beams are refracted toward each other. *Concave lenses* are thinner in the middle than at the edges. When light beams pass through a concave lens, the beams are refracted away from each other.

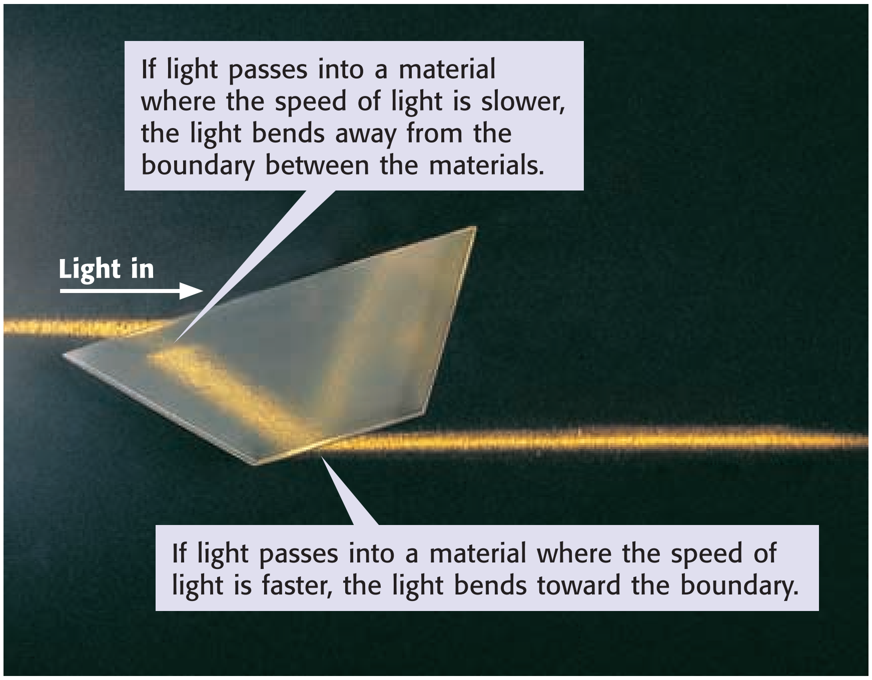


Figure 5 *Light travels more slowly through glass than it does through air. So, light refracts as it passes at an angle from air to glass or from glass to air. Notice that the light is also reflected inside the prism.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

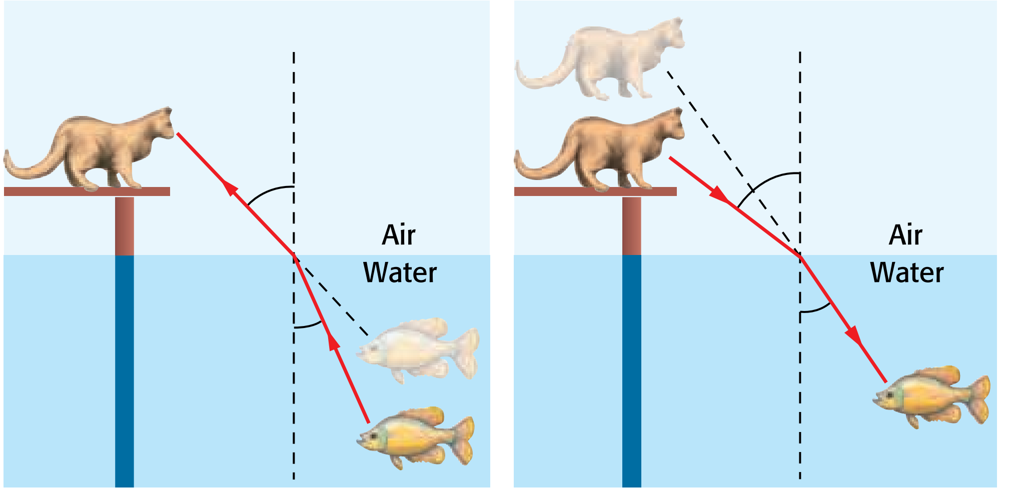


Figure 6 *Because of refraction, the cat and the fish see optical illusions. To the cat, the fish appears closer than it really is. To the fish, the cat appears farther away than it actually is.*

Refraction and Optical Illusions

Usually, when you look at an object, the light reflecting off the object travels in a straight line from the object to your eye. Your brain always interprets light as traveling in straight lines. But when you look at an object that is underwater, the light reflecting off the object does not travel in a straight line. Instead, it refracts. **Figure 6** shows how refraction creates an optical illusion. This kind of illusion causes a person's feet to appear separated from the legs when the person is wading.

Refraction and Color Separation

White light is composed of all the wavelengths of visible light. The different wavelengths of visible light are seen by humans as different colors. When white light is refracted, the amount that the light bends depends on its wavelength. Waves with short wavelengths bend more than waves with long wavelengths. As shown in **Figure 7,** white light can be separated into different colors during refraction. Color separation by refraction is responsible for the formation of rainbows. Rainbows are created when sunlight is refracted by water droplets.

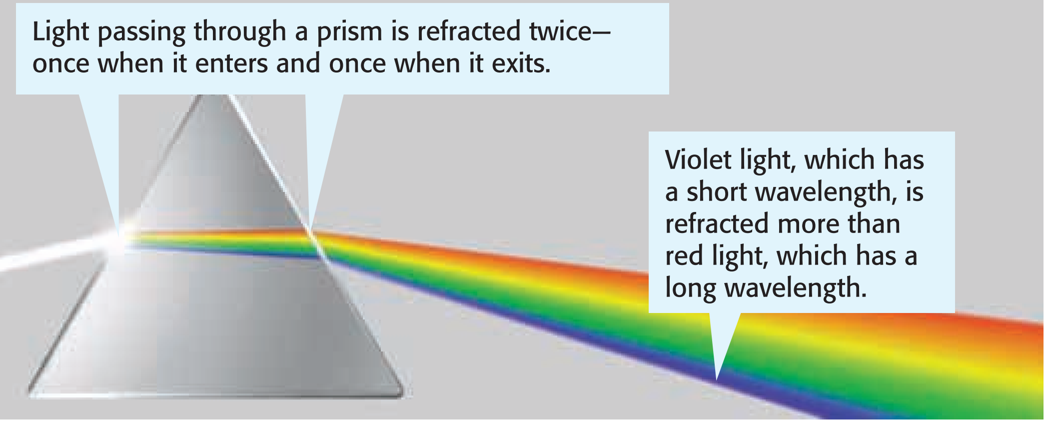


Figure 7 *A prism is a piece of glass that separates white light into the colors of visible light by refraction.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Quick Lab

Refraction Rainbow

1. **Tape** a **piece of construction paper** over the end of a **flashlight.** Use **scissors** to cut a slit in the paper.
2. Turn on the flashlight, and lay it on a table. Place a **prism** on end in the beam of light.
3. Slowly rotate the prism until you can see a rainbow on the surface of the table. Draw a diagram of the light beam, the prism, and the rainbow.

Diffraction

Refraction isn't the only way light waves are bent. **Diffraction** is the bending of waves around barriers or through openings. The amount a wave diffracts depends on its wavelength and the size of the barrier or the opening. The greatest amount of diffraction occurs when the barrier or opening is the same size or smaller than the wavelength.

diffraction a change in the direction of a wave when the wave finds an obstacle or an edge, such as an opening

Reading Check **The amount a wave diffracts depends on what two things?**

Diffraction and Wavelength

The wavelength of visible light is very small—about 100 times thinner than a human hair! So, a light wave cannot bend very much by diffraction unless it passes through a narrow opening, around sharp edges, or around a small barrier, as shown in **Figure 8.**

Light waves cannot diffract very much around large obstacles, such as buildings. Thus, you can't see around corners. But light waves always diffract a small amount. You can observe light waves diffracting if you examine the edges of a shadow. Diffraction causes the edges of shadows to be blurry.

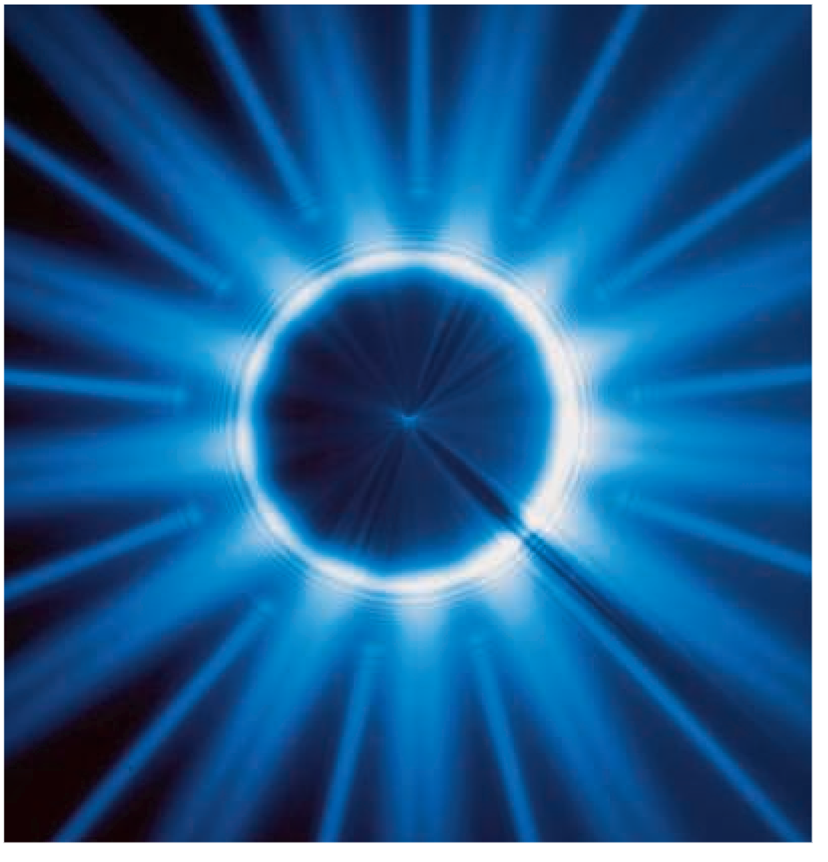


Figure 8 *This diffraction pattern is made by light of a single wavelength shining around the edges of a very tiny disk.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

interference the combination of two or more waves that results in a single wave

Interference

Interference is a wave interaction that happens when two or more waves overlap. Overlapping waves can combine by constructive or destructive interference.

Constructive Interference

When waves combine by *constructive interference,* the resulting wave has a greater amplitude, or height, than the individual waves had. Constructive interference of light waves can be seen when light of one wavelength shines through two small slits onto a screen. The light on the screen will appear as a series of alternating bright and dark bands, as shown in **Figure 9.** The bright bands result from light waves combining through constructive interference.

Reading Check What is constructive interference?

Destructive Interference

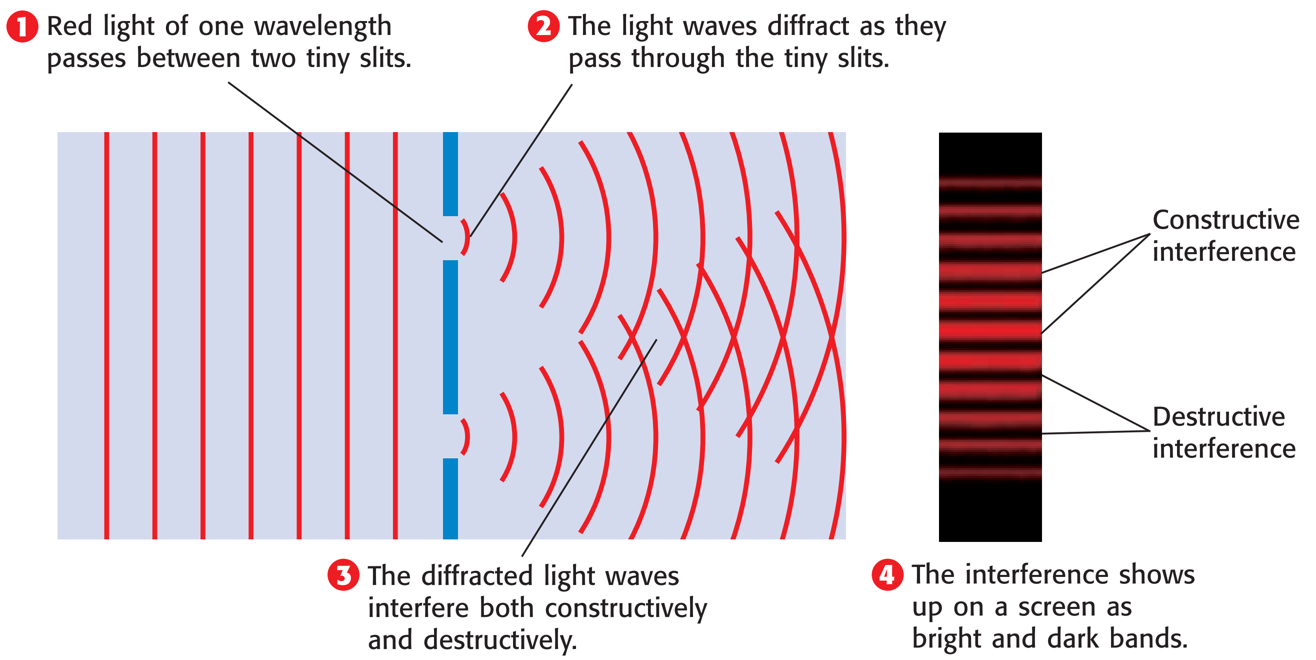
When waves combine by *destructive interference,* the resulting wave has a smaller amplitude than the individual waves had. So, when light waves interfere destructively, the result will be dimmer light. Destructive interference forms the dark bands seen in **Figure 9.**

You do not see constructive or destructive interference of white light. To understand why, remember that white light is composed of waves with many different wavelengths. The waves rarely line up to combine in total destructive interference.

INTERNET ACTIVITY

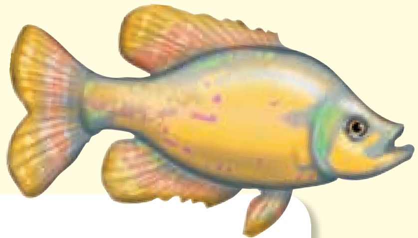
For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HP5LGTW.**

Figure 9 **Constructive and Destructive Interference**



Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION
Review



Summary

- The law of reflection states that the angle of incidence is equal to the angle of reflection.
- Things that are luminous can be seen because they produce their own light. Things that are illuminated can be seen because light reflects off them.
- Absorption is the transfer of light energy to particles of matter. Scattering is an interaction of light with matter that causes light to change direction.
- Refraction of light waves can create optical illusions and can separate white light into separate colors.
- How much light waves diffract depends on the light's wavelength. Light waves diffract more when traveling through a narrow opening.
- Interference can be constructive or destructive. Interference of light waves can cause bright and dark bands.

Using Key Terms

For each pair of terms, explain how the meanings of the terms differ.

1. *refraction* and *diffraction*
2. *absorption* and *scattering*

Understanding Key Ideas

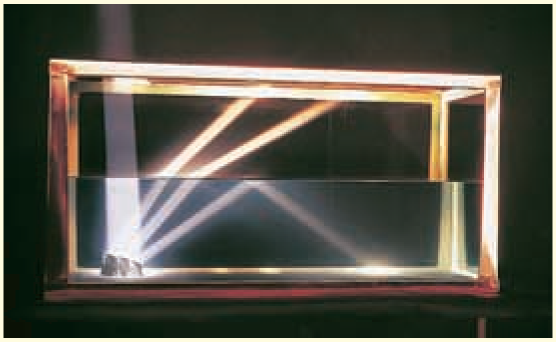
3. Which light interaction explains why you can see things that do not produce their own light?
   a. absorption
   b. reflection
   c. refraction
   d. scattering
4. Describe how absorption and scattering can affect a beam of light.
5. Why do objects that are underwater look closer than they actually are?
6. How does a prism separate white light into different colors?
7. What is the relationship between diffraction and the wavelength of light?

Critical Thinking

8. **Applying Concepts** Explain why you can see your reflection on a spoon but not on a piece of cloth.
9. **Making Inferences** The planet Mars does not produce light. Explain why you can see Mars shining like a star at night.
10. **Making Comparisons** Compare constructive interference and destructive interference.

Interpreting Graphics

Use the image below to answer the questions that follow.



11. Why doesn't the large beam of light bend like the two beams in the middle of the tank?
12. Which light interaction explains what is happening to the bottom light beam?

SCILINKS® NSTA
Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Reflection and Refraction
SciLinks code: HSM1283

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 3

Light and Color

Why are strawberries red and bananas yellow? How can a soda bottle be green, yet you can still see through it?

If white light is made of all the colors of light, how do things get their color from white light? Why aren't all things white in white light? Good questions! To answer these questions, you need to know how light interacts with matter.

READING WARM-UP

Objectives

- Name and describe the three ways light interacts with matter.
- Explain how the color of an object is determined.
- Explain why mixing colors of light is called *color addition*.
- Describe why mixing colors of pigments is called *color subtraction*.

Terms to Learn

transmission
transparent
translucent
opaque
pigment

READING STRATEGY

Discussion Read this section silently. Write down questions that you have about this section. Discuss your questions in a small group.

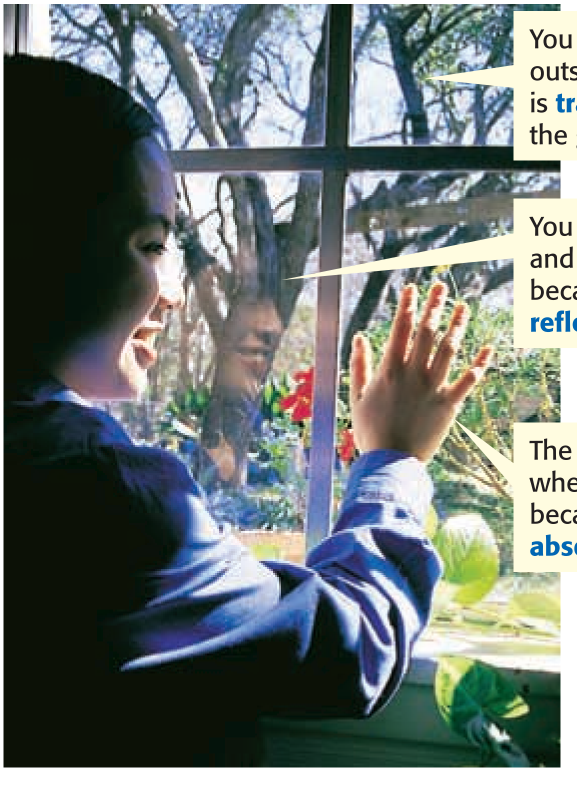
Light and Matter

When light strikes any form of matter, it can interact with the matter in three different ways—the light can be reflected, absorbed, or transmitted.

Reflection happens when light bounces off an object. Reflected light allows you to see things. Absorption is the transfer of light energy to matter. Absorbed light can make things feel warmer. **Transmission** is the passing of light through matter. You see the transmission of light all the time. All of the light that reaches your eyes is transmitted through air. Light can interact with matter in several ways at the same time. Look at **Figure 1.** Light is transmitted, reflected, and absorbed when it strikes the glass in a window.

transmission the passing of light or other form of energy through matter

Figure 1 Transmission, Reflection, and Absorption



You can see objects outside because light is **transmitted** through the glass.

You can see the glass and your reflection in it because light is **reflected** off the glass.

The glass feels warm when you touch it because some light is **absorbed** by the glass.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 2 **Transparent, Translucent, and Opaque**

Transparent plastic makes it easy to see what you are having for lunch.

Translucent wax paper makes it a little harder to see exactly what's for lunch.

Opaque aluminum foil makes it impossible to see your lunch without unwrapping it.

Types of Matter

Matter through which visible light is easily transmitted is said to be **transparent.** Air, glass, and water are examples of transparent matter. You can see objects clearly when you view them through transparent matter.

Sometimes, windows in bathrooms are made of frosted glass. If you look through one of these windows, you will see only blurry shapes. You can't see clearly through a frosted window because it is translucent (trans LOO suhnt). **Translucent** matter transmits light but also scatters the light as it passes through the matter. Wax paper is an example of translucent matter.

Matter that does not transmit any light is said to be **opaque** (oh PAYK). You cannot see through opaque objects. Metal, wood, and this book are examples of opaque objects. You can compare transparent, translucent, and opaque matter in **Figure 2.**

transparent describes matter that allows light to pass through with little interference

translucent describes matter that transmits light but that does not transmit an image

opaque describes an object that is not transparent or translucent

Reading Check **List two examples of translucent objects.** (*See the Appendix for answers to Reading Checks.*)

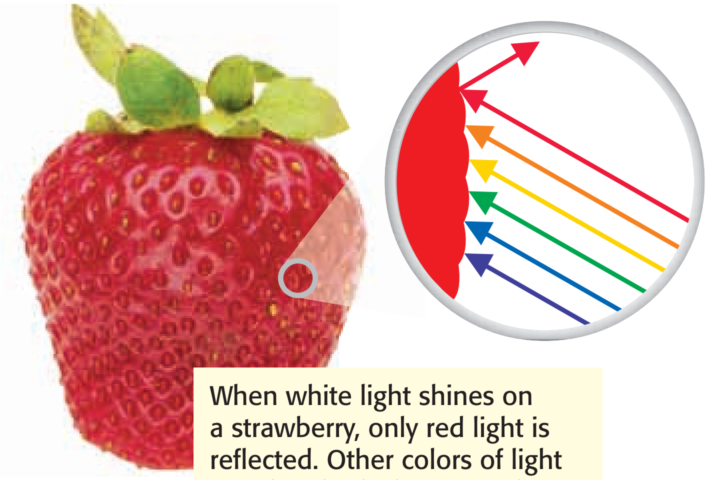
Colors of Objects

How is an object's color determined? Humans see different wavelengths of light as different colors. For example, humans see long wavelengths as red and short wavelengths as violet. And, some colors, like pink and brown, are seen when certain combinations of wavelengths are present.

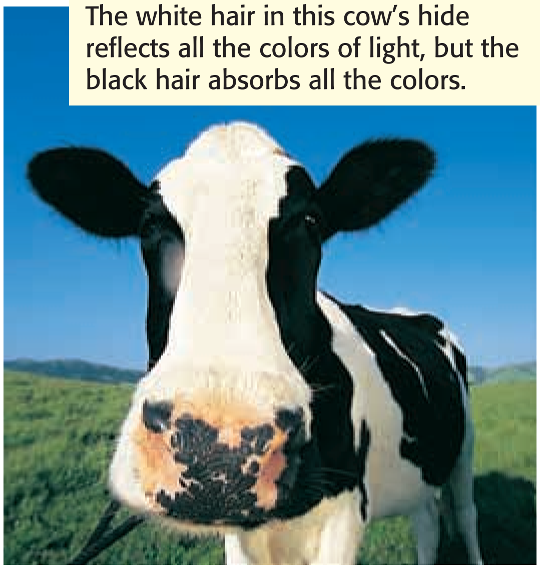
The color that an object appears to be is determined by the wavelengths of light that reach your eyes. Light reaches your eyes after being reflected off an object or after being transmitted through an object. When your eyes receive the light, they send signals to your brain. Your brain interprets the signals as colors.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 3 **Opaque Objects and Color**



When white light shines on a strawberry, only red light is reflected. Other colors of light are absorbed. Therefore, the strawberry looks red to you.



The white hair in this cow's hide reflects all the colors of light, but the black hair absorbs all the colors.

Colors of Opaque Objects

When white light strikes a colored opaque object, some colors of light are absorbed, and some are reflected. Only the light that is reflected reaches your eyes and is detected. So, the colors of light that are reflected by an opaque object determine the color you see. For example, if a sweater reflects blue light and absorbs all other colors, you will see that the sweater is blue. Another example is shown on the left in **Figure 3.**

What colors of light are reflected by the cow shown on the right in **Figure 3**? Remember that white light includes all colors of light. So, white objects—such as the white hair in the cow's hide—appear white because all the colors of light are reflected. On the other hand, black is the absence of color. When light strikes a black object, all the colors are absorbed.

Reading Check **What happens when white light strikes a colored opaque object?**

Colors of Transparent and Translucent Objects

The color of transparent and translucent objects is determined differently than the color of opaque objects. Ordinary window glass is colorless in white light because it transmits all the colors that strike it. But some transparent objects are colored. When you look through colored transparent or translucent objects, you see the color of light that was transmitted through the material. The other colors were absorbed, as shown in **Figure 4.**

Figure 4 *This bottle is green because the plastic transmits green light.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

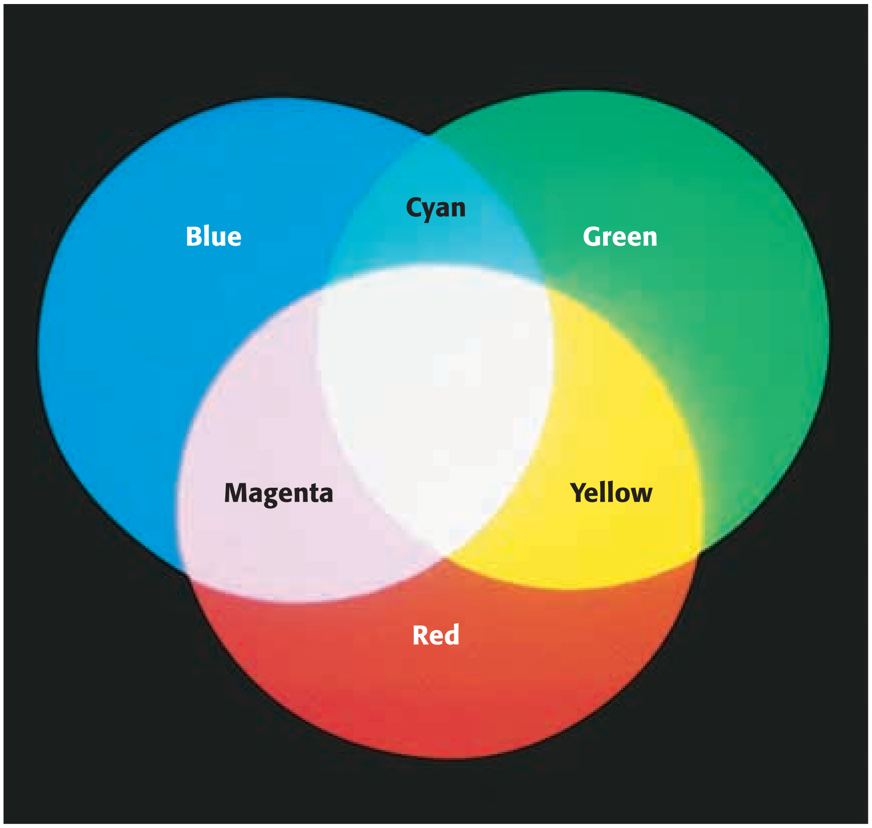


Figure 5 *Primary colors of light—written in white—combine to produce white light. Secondary colors of light—written in black—are the result of two primary colors added together.*

Mixing Colors of Light

In order to get white light, you must combine all colors of light, right? This method is one way of doing it. But you can also get light that appears white by adding just three colors of light together—red, blue, and green. The combination of these three colors is shown in **Figure 5.** In fact, these three colors can be combined in different ratios to produce many colors. Red, blue, and green are called the *primary colors of light*.

Color Addition

When colors of light combine, you see different colors. Combining colors of light is called *color addition*. When two primary colors of light are added together, you see a *secondary color of light*. The secondary colors of light are cyan (blue plus green), magenta (blue plus red), and yellow (red plus green). **Figure 5** shows how secondary colors of light are formed.

Light and Color Television

The colors on a color television are produced by color addition of the primary colors of light. A television screen is made up of groups of tiny red, green, and blue dots. Each dot will glow when the dot is hit by an electron beam. The colors given off by the glowing dots add together to produce all the different colors you see on the screen.

SCHOOL to HOME

Television Colors

Turn on a color television. Ask an adult to carefully sprinkle a few tiny drops of water onto the television screen. Look closely at the drops of water, and discuss what you see. In your **science journal,** write a description of what you saw.

ACTIVITY

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Mixing Colors of Pigment

If you have ever tried mixing paints in art class, you know that you can't make white paint by mixing red, blue, and green paint. The difference between mixing paint and mixing light is due to the fact that paint contains pigments.

Pigments and Color

pigment a substance that gives another substance or a mixture its color

A **pigment** is a material that gives a substance its color by absorbing some colors of light and reflecting others. Almost everything contains pigments. Chlorophyll (KLAWR uh FIL) and melanin (MEL uh nin) are two examples of pigments. Chlorophyll gives plants a green color, and melanin gives your skin its color.

Reading Check **What is a pigment?**

Color Subtraction

Each pigment absorbs at least one color of light. Look at **Figure 6.** When you mix pigments together, more colors of light are absorbed or taken away. So, mixing pigments is called *color subtraction*.

The *primary pigments* are yellow, cyan, and magenta. They can be combined to produce any other color. In fact, every color in this book was produced by using just the primary pigments and black ink. The black ink was used to provide contrast to the images. **Figure 7** shows how the four pigments combine to produce many different colors.

Quick Lab

Rose-Colored Glasses?

1. Obtain **four plastic filters**—red, blue, yellow, and green.
2. Look through one filter at an object across the room. Describe the object's color.
3. Repeat step 2 with each of the filters.
4. Repeat step 2 with two or three filters together.
5. Why do you think the colors change when you use more than one filter?
6. Write your observations and answers.

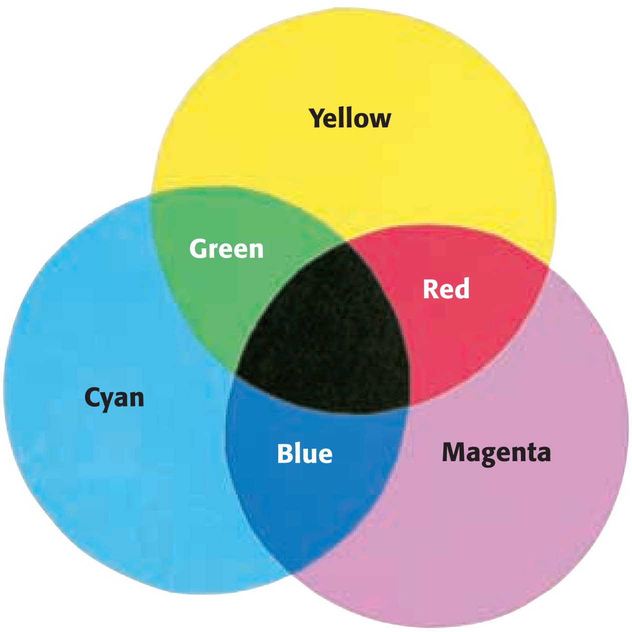


Figure 6 *Primary pigments—written in black—combine to produce black. Secondary pigments—written in white—are the result of the subtraction of two primary pigments.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 7 **Color Subtraction and Color Printing**

The picture of the balloon on the left was made by overlapping yellow ink, cyan ink, magenta ink, and black ink.

Yellow Cyan Magenta Black

SECTION Review

Summary

- Objects are transparent, translucent, or opaque, depending on their ability to transmit light.
- Colors of opaque objects are determined by the color of light that they reflect.
- Colors of translucent and transparent objects are determined by the color of light they transmit.
- White light is a mixture of all colors of light.
- Light combines by color addition. The primary colors of light are red, blue, and green.
- Pigments give objects color. Pigments combine by color subtraction. The primary pigments are magenta, cyan, and yellow.

Using Key Terms

1. Use the following terms in the same sentence: *transmission* and *transparent*.
2. In your own words, write a definition for each of the following terms: *translucent* and *opaque*.

Understanding Key Ideas

3. You can see through a car window because the window is
   a. opaque.
   b. translucent.
   c. transparent.
   d. transmitted.
4. Name and describe three different ways light interacts with matter.
5. How is the color of an opaque object determined?
6. Describe how the color of a transparent object is determined.
7. What are the primary colors of light, and why are they called *primary colors*?
8. What four colors of ink were used to print this book?

Critical Thinking

9. **Applying Concepts** What happens to the different colors of light when white light shines on an opaque violet object?
10. **Analyzing Ideas** Explain why mixing colors of light is called *color addition* but mixing pigments is called *color subtraction*.

Interpreting Graphics

11. Look at the image below. The red rose was photographed in red light. Explain why the leaves appear black and the petals appear red.

SCILINKS

NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Colors

SciLinks code: HSM0314

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 4

Light and Sight

READING WARM-UP

Objectives

- Identify the parts of the human eye, and describe their functions.
- Describe three common vision problems.
- Describe surgical eye correction.

Terms to Learn

nearsightedness
farsightedness

READING STRATEGY

Reading Organizer As you read this section, make a flowchart of how the eye works.

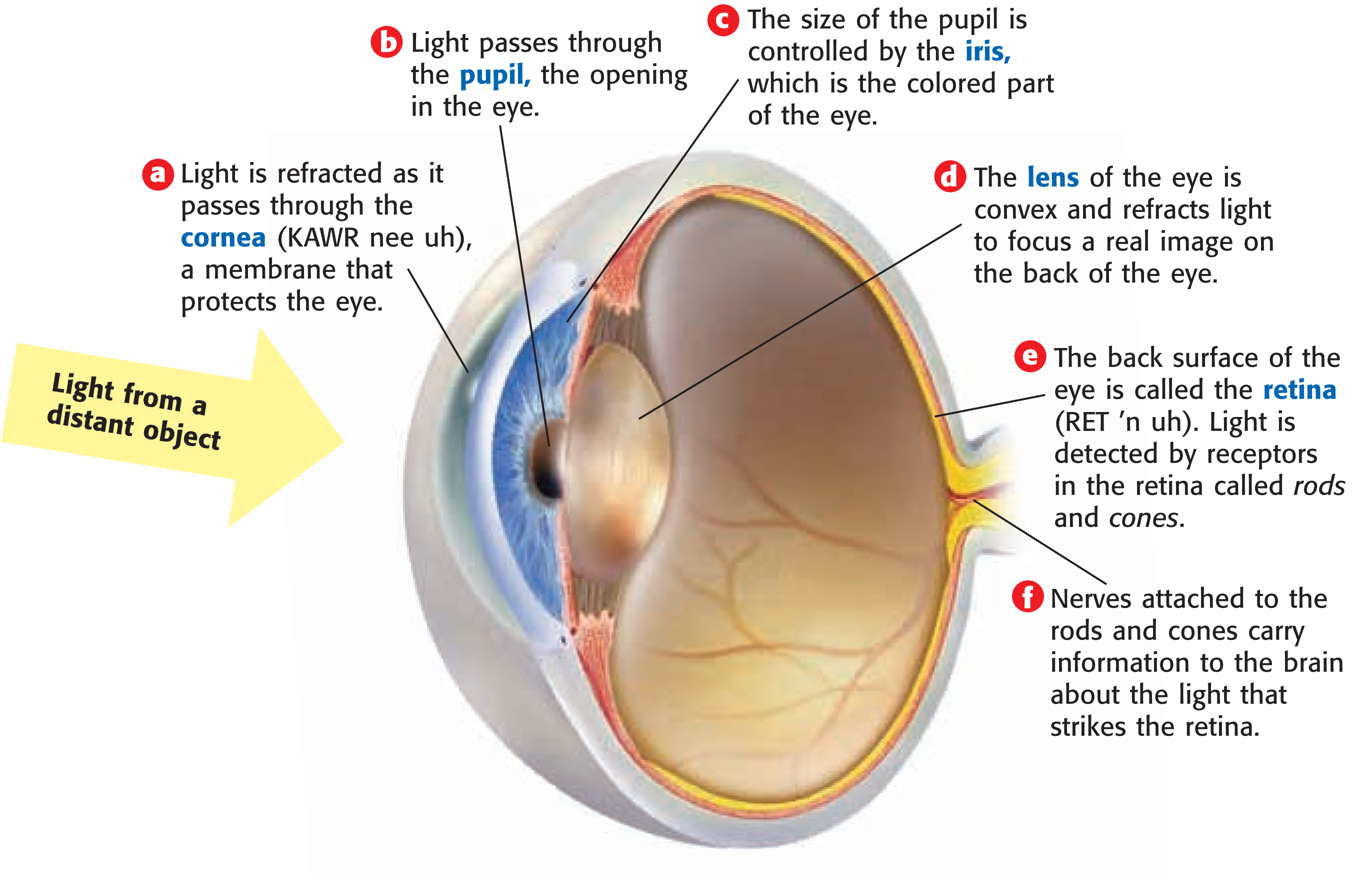
When you look around, you can see objects both near and far. You can also see the different colors of the objects.

You see objects that produce their own light because the light is detected by your eyes. You see all other objects because light reflected from the objects enters your eyes. But how do your eyes work, and what causes people to have vision problems?

How You Detect Light

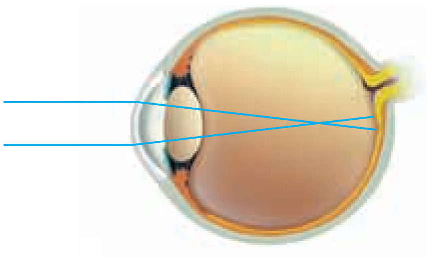
The kind of electromagnetic waves that can be detected by your eyes is called *visible light*. Your eye gathers visible light to form the images that you see. The steps of this process are shown in **Figure 1.** Muscles around the lens change the thickness of the lens so that objects at different distances can be seen in focus. The light that forms the real image is detected by receptors in the retina called *rods* and *cones*. Rods can detect very dim light. Cones detect colors in bright light.

Figure 1 How Your Eyes Work

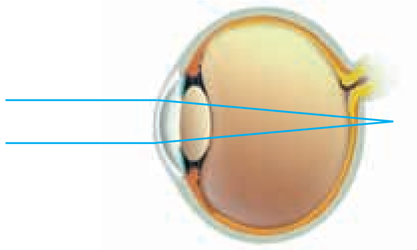


Copyright © by Holt, Rinehart and Winston. All rights reserved.

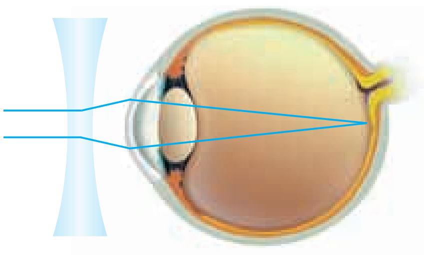
Figure 2 **Correcting Nearsightedness and Farsightedness**



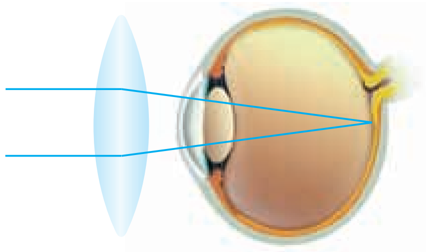
Nearsightedness happens when the eye is too long, which causes the lens to focus light in front of the retina.



Farsightedness happens when the eye is too short, which causes the lens to focus light behind the retina.



A **concave lens** placed in front of a nearsighted eye refracts the light outward. The lens in the eye can then focus the light on the retina.



A **convex lens** placed in front of a farsighted eye focuses the light. The lens in the eye can then focus the light on the retina.

Common Vision Problems

People who have normal vision can clearly see objects that are close and objects that are far away. They can also tell the difference between all colors of visible light. But because the eye is complex, it's no surprise that many people have defects in their eyes that affect their vision.

Nearsightedness and Farsightedness

The lens of a properly working eye focuses light on the retina. So, the images formed are always clear. Two common vision problems happen when light is not focused on the retina, as shown in **Figure 2.** **Nearsightedness** happens when a person's eye is too long. A nearsighted person can see something clearly only if it is nearby. Objects that are far away look blurry. **Farsightedness** happens when a person's eye is too short. A farsighted person can see faraway objects clearly. But things that are nearby look blurry. **Figure 2** also shows how these vision problems can be corrected with glasses.

nearsightedness a condition in which the lens of the eye focuses distant objects in front of rather than on the retina

farsightedness a condition in which the lens of the eye focuses distant objects behind rather than on the retina

Reading Check **What causes nearsightedness and farsightedness?** (*See the Appendix for answers to Reading Checks.*)

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 3 *The photo on the left is what a person who has normal vision sees. The photo on the right is a simulation of what a person who has red-green color deficiency might see.*

Color Deficiency

About 5% to 8% of men and 0.5% of women in the world have *color deficiency,* or colorblindness. The majority of people who have color deficiency can't tell the difference between shades of red and green or can't tell red from green. **Figure 3** compares what a person with normal vision sees with what a person who has red-green color deficiency sees. Color deficiency cannot be corrected.

Color deficiency happens when the cones in the retina do not work properly. The three kinds of cones are named for the colors they detect most—red, green, or blue. But each kind can detect many colors of light. A person who has normal vision can see all colors of visible light. But in some people, the cones respond to the wrong colors. Those people see certain colors, such as red and green, as a different color, such as yellow.

Reading Check **What are the three kinds of cones?**

CONNECTION TO Biology

Color Deficiency and Genes The ability to see color is a sex-linked genetic trait. Certain genes control which colors of light the cones detect. If these genes are defective in a person, that person will have color deficiency. A person needs one set of normal genes to have normal color vision. Genes that control the red cones and the green cones are on the X chromosome. Women have two X chromosomes, but men have only one. So, men are more likely than women to lack a set of these genes and to have red-green color deficiency. Research two other sex-linked traits, and make a graph comparing the percentage of men and women who have the traits.

ACTIVITY

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Surgical Eye Correction

Using surgery to correct nearsightedness or farsightedness is possible. Surgical eye correction works by reshaping the patient's cornea. Remember that the cornea refracts light. So, reshaping the cornea changes how light is focused on the retina.

To prepare for eye surgery, an eye doctor uses a machine to measure the patient's corneas. A laser is then used to reshape each cornea so that the patient gains perfect or nearly perfect vision. **Figure 4** shows a patient undergoing eye surgery.

Risks of Surgical Eye Correction

Although vision-correction surgery can be helpful, it has some risks. Some patients report glares or double vision. Others have trouble seeing at night. Other patients lose vision permanently. People under 20 years old shouldn't have vision-correction surgery because their vision is still changing.

Figure 4 *An eye surgeon uses a very precise laser to reshape this patient's cornea.*

SECTION Review

Summary

- The human eye has several parts, including the cornea, the pupil, the iris, the lens, and the retina.
- Nearsightedness and farsightedness happen when light is not focused on the retina. Both problems can be corrected with glasses or eye surgery.
- Color deficiency is a condition in which cones in the retina respond to the wrong colors.
- Eye surgery can correct some vision problems.

Using Key Terms

1. Use each of the following terms in a separate sentence: *nearsightedness* and *farsightedness*.

Understanding Key Ideas

2. A person who is nearsighted will have the most trouble reading
   a. a computer screen in front of him or her.
   b. a book in his or her hands.
   c. a street sign across the street.
   d. the title of a pamphlet on a nearby table.
3. List the parts of the eye, and describe what each part does.
4. What are three common vision problems?
5. How are nearsightedness and farsightedness corrected?
6. Describe surgical eye correction.
7. What do the rods and cones in the eye do?

Math Skills

8. About 0.5% of women have a color deficiency. How many women out of 200 have a color deficiency?

Critical Thinking

9. **Forming Hypotheses** Why do you think color deficiency cannot be corrected?
10. **Expressing Opinions** Would you have surgical eye correction? Explain your reasons.

SCILINKS
NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: The Eye
SciLinks code: HSM0560

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Skills Practice Lab

OBJECTIVES

Use flashlights to mix colors of light by color addition.

Use paints to mix colors of pigments by color subtraction.

MATERIALS

Part A

- colored filters, red, green, and blue (1 of each)
- flashlights (3)
- paper, white
- tape, masking

Part B

- cups, small plastic or paper (2)
- paintbrush
- paper, white
- ruler, metric
- tape, masking
- water
- watercolor paints

SAFETY

Mixing Colors

Mix two colors, such as red and green, and you create a new color. Is the new color brighter or darker? Color and brightness depend on the light that reaches your eye. And what reaches your eye depends on whether you are adding colors (mixing colors of light) or subtracting colors (mixing colors of pigments). In this activity, you will do both types of color formation and see the results firsthand!

Part A: Color Addition

Procedure

1. Tape a colored filter over each flashlight lens.
2. In a darkened room, shine the red light on a sheet of white paper. Then, shine the green light next to the red light. You should have two circles of light, one red and one green, next to each other.
3. Move the flashlights so that the circles overlap by half their diameter. What color is formed where the circles overlap? Is the mixed area brighter or darker than the single-color areas? Record your observations.

4. Repeat steps 2 and 3 with the red and blue lights.
5. Now, shine all three lights at the same point on the paper. Record your observations.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Analyze the Results

1. **Describing Events** In general, when you mixed two colors, was the result brighter or darker than the original colors?
2. **Explaining Events** In step 5, you mixed all three colors. Was the resulting color brighter or darker than when you mixed two colors? Explain your observations in terms of color addition.

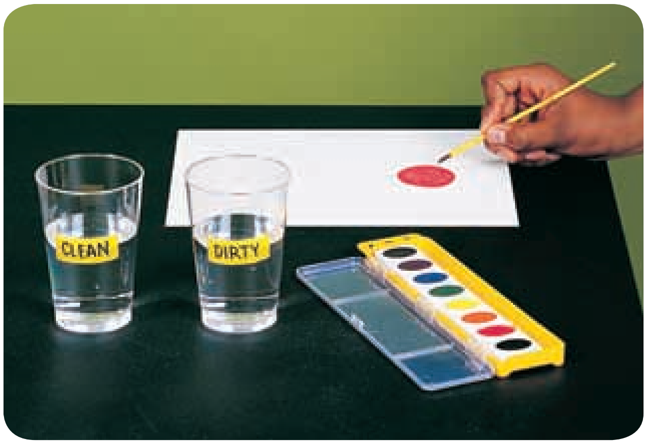
Draw Conclusions

3. **Making Predictions** What do you think would happen if you mixed together all the colors of light? Explain your answer.

Part B: Color Subtraction

Procedure

1. Place a piece of masking tape on each cup. Label one cup "Clean" and the other cup "Dirty." Fill each cup about half full with water.
2. Wet the paintbrush thoroughly in the "Clean" cup. Using the watercolor paints, paint a red circle on the white paper. The circle should be approximately 4 cm in diameter.
3. Clean the brush by rinsing it first in the "Dirty" cup and then in the "Clean" cup.
4. Paint a blue circle next to the red circle. Then, paint half the red circle with the blue paint.
5. Examine the three areas: red, blue, and mixed. What color is the mixed area? Does it appear brighter or darker than the red and blue areas? Record your observations.
6. Clean the brush by repeating Step 3. Paint a green circle 4 cm in diameter, and then paint half the blue circle with green paint.



7. Examine the green, blue, and mixed areas. Record your observations.
8. Now add green paint to the mixed red-blue area so that you have an area that is a mixture of red, green, and blue paint. Clean the brush again.
9. Finally, record your observations of this new mixed area.

Analyze the Results

1. **Identifying Patterns** In general, when you mixed two colors, was the result brighter or darker than the original colors?
2. **Analyzing Results** In step 8, you mixed all three colors. Was the result brighter or darker than the result from mixing two colors? Explain what you saw in terms of color subtraction.

Draw Conclusions

3. **Drawing Conclusions** Based on your results, what do you think would happen if you mixed all the colors of paint? Explain your answer.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Chapter Review

USING KEY TERMS

Complete each of the following sentences by choosing the correct term from the word bank.

interference	radiation
farsightedness	opaque
translucent	transmission
electromagnetic wave	nearsightedness

1. _____ is the transfer of energy by electromagnetic waves.

2. _____ is a wave interaction that occurs when two or more waves overlap and combine.

3. A person who has _____ has trouble reading a book.

4. Light is a kind of _____ and can therefore travel through matter and space.

5. During _____, light travels through an object.

UNDERSTANDING KEY IDEAS

Multiple Choice

6. Electromagnetic waves transmit
   - **a.** charges.
   - **b.** fields.
   - **c.** matter.
   - **d.** energy.

7. Objects that transmit light easily are
   - **a.** opaque.
   - **b.** translucent.
   - **c.** transparent.
   - **d.** colored.

8. You can see yourself in a mirror because of
   - **a.** absorption.
   - **b.** scattering.
   - **c.** regular reflection.
   - **d.** diffuse reflection.

9. Shadows have blurry edges because of
   - **a.** diffraction.
   - **b.** scattering.
   - **c.** diffuse reflection.
   - **d.** refraction.

10. What color of light is produced when red light is added to green light?
    - **a.** cyan
    - **b.** blue
    - **c.** yellow
    - **d.** white

11. Prisms produce the colors of the rainbow through
    - **a.** reflection.
    - **b.** refraction.
    - **c.** diffraction.
    - **d.** interference.

12. A vision problem that happens when light is focused in front of the retina is
    - **a.** farsightedness.
    - **b.** nearsightedness.
    - **c.** color deficiency.
    - **d.** None of the above

13. Electromagnetic waves are made of
    - **a.** vibrating particles.
    - **b.** vibrating charged particles.
    - **c.** vibrating electric and magnetic fields.
    - **d.** All of the above

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Short Answer

14. What kind of lens should be put in the eyeglasses of a person who cannot focus on nearby objects? Explain.

15. Why is it difficult to see through glass that has frost on it?

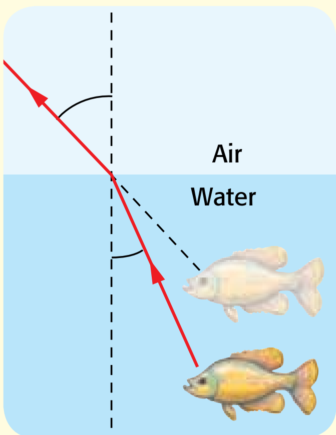
Math Skills

16. Calculate the time it takes for light from the sun to reach Mercury. Mercury is 54,900,000 km away from the sun.

CRITICAL THINKING

17. **Concept Mapping** Use the following terms to create a concept map: *light, matter, reflection, absorption,* and *transmission.*

18. **Applying Concepts** A tern is a type of bird that dives underwater to catch fish. When a young tern begins learning to catch fish, the bird is rarely successful. The tern has to learn that when a fish appears to be in a certain place underwater, the fish is actually in a slightly different place. Why does the tern see the fish in the wrong place?



19. **Evaluating Conclusions** Imagine that you are teaching your younger brother about light. You tell him that white light is light of all the colors of the rainbow combined. But your brother says that you are wrong because mixing different colors of paint produces black and not white. Explain why your brother's conclusion is wrong.

20. **Making Inferences** If you look around a parking lot during the summer, you might see sunshades set up in the windshields of cars. How do sunshades help keep the insides of cars cool?

INTERPRETING GRAPHICS

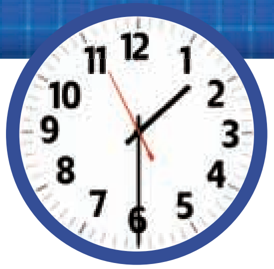
21. Each of the pictures below shows the effects of a wave interaction of light. Identify the interaction involved.

a.

b.

c.

Copyright © by Holt, Rinehart and Winston. All rights reserved.



Standardized Test Preparation

EOG Prep

READING

Read each of the passages below. Then, answer the questions that follow each passage.

Passage 1 Jaundice occurs in some infants when bilirubin—a pigment in healthy red blood cells—builds up in the bloodstream as blood cells break down. This excess bilirubin is deposited in the skin, giving the skin a yellowish hue. Jaundice is not dangerous if treated quickly. If left untreated, it can lead to brain damage.

The excess bilirubin in the skin is best broken down by bright blue light. For this reason, hospitals hang special blue fluorescent lights above the cribs of newborns needing treatment. The blue light is sometimes balanced with light of other colors so that doctors and nurses can be sure the baby is not blue from a lack of oxygen.

1. Which of the following is a fact in the passage?

A Jaundice is always very dangerous.
B Bilirubin in the skin of infants can be broken down with bright blue light.
C Excess bilirubin in the skin gives the skin a bright blue hue.
D Blue lights can make a baby blue from a lack of oxygen.

2. What is the purpose of this passage?

F to explain what jaundice is and how it is treated
G to warn parents about shining blue light on their babies
H to persuade light bulb manufacturers to make blue light bulbs
I to explain the purpose of bilirubin in red blood cells

Passage 2 If you have ever looked inside a toaster while toasting a piece of bread, you may have seen thin wires or bars glowing red. The wires give off energy as light when heated to a high temperature. Light produced by hot objects is called *incandescent light*. Most of the lamps in your home probably use incandescent light bulbs.

Sources of incandescent light also release a large amount of thermal energy. Thermal energy is sometimes called *heat energy*. Sometimes, thermal energy from incandescent light is used to cook food or to warm a room. But often this thermal energy is not used for anything. For example, the thermal energy given off by light bulbs is not very useful.

1. What does the word *thermal* mean, based on its use in the passage?

A light
B energy
C heat
D food

2. What is incandescent light?

F light used for cooking food
G light that is red in color
H light that is not very useful
I light produced by hot objects

3. Which of the following can be inferred from the passage?

A Sources of incandescent light are rarely found in an average home.
B A toaster uses thermal energy to toast bread.
C Incandescent light from light bulbs is often used to cook food.
D The thermal energy produced by incandescent light sources is always useful.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

INTERPRETING GRAPHICS

The angles of refraction in the table were measured when a beam of light entered the material from air at a 45° angle. Use the table below to answer the questions that follow.

Material and Refraction		
Material	Index of refraction	Angle of refraction
Diamond	2.42	17°
Glass	1.52	28°
Quartz	1.46	29°
Water	1.33	32°

1. Which material has the highest index of refraction?

A diamond
B glass
C quartz
D water

2. Which material has the greatest angle of refraction?

F diamond
G glass
H quartz
I water

3. Which of the following statements **best** describes the data in the table?

A The higher the index of refraction, the greater the angle of refraction.
B The higher the index of refraction, the smaller the angle of refraction.
C The greater the angle of refraction, the higher the index of refraction.
D There is no relationship between the index of refraction and the angle of refraction.

4. Which two materials would be the most difficult to separate by observing only their angles of refraction?

F diamond and glass
G glass and quartz
H quartz and water
I water and diamond

MATH

Read each question below, and choose the best answer.

1. A square metal plate has an area of 46.3 cm^2. The length of one side of the plate is between which two values?

A 4 cm and 5 cm
B 5 cm and 6 cm
C 6 cm and 7 cm
D 7 cm and 8 cm

2. A jet was flying over the Gulf of Mexico at an altitude of 2,150 m. Directly below the jet, a submarine was at a depth of −383 m. What was the distance between the jet and the submarine?

F −2,533 m
G −1,767 m
H 1,767 m
I 2,533 m

3. The speed of light in a vacuum is exactly 299,792,458 m/s. Which of the following is a good estimate of the speed of light?

A 3.0×10^{-8} m/s
B 2.0×10^{8} m/s
C 3.0×10^{8} m/s
D 3.0×10^{9} m/s

4. The wavelength of the yellow light produced by a sodium vapor lamp is 0.000000589 m. Which of the following is equal to the wavelength of the sodium lamp's yellow light?

F -5.89×10^{7} m
G 5.89×10^{-9} m
H 5.89×10^{-7} m
I 5.89×10^{7} m

5. Amira purchased a box of light bulbs for \$3.81. There are three light bulbs in the box. What is the cost per light bulb?

A \$0.79
B \$1.06
C \$1.27
D \$11.43

Standardized Test Preparation

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Science in Action

Weird Science

Fireflies Light the Way

Just as beams of light from lighthouses warn boats of approaching danger, the light of an unlikely source—fireflies—is being used by scientists to warn food inspectors of bacterial contamination.

Fireflies use an enzyme called *luciferase* to make light. Scientists have taken the gene from fireflies that tells cells how to make luciferase. They put this gene into a virus that preys on bacteria. The virus is not harmful to humans and can be mixed into meat. When the virus infects bacteria in the meat, the virus transfers the gene into the genes of the bacteria. The bacteria then produce luciferase and glow! So, if a food inspector sees glowing meat, the inspector knows that the meat is contaminated with bacteria.

Social Studies ACTIVITY

WRITING SKILL Many cultures have myths to explain certain natural phenomena. Read some of these myths. Then, write your own myth titled "How Fireflies Got Their Fire."

Science, Technology, and Society

It's a Heat Wave

In 1946, Percy Spencer visited a laboratory belonging to Raytheon—the company he worked for. When he stood near a device called a *magnetron,* he noticed that a candy bar in his pocket melted. Spencer hypothesized that the microwaves produced by the magnetron caused the candy bar to warm up and melt. To test his hypothesis, Spencer put a bag of popcorn kernels next to the magnetron. The microwaves heated the kernels, causing them to pop! Spencer's simple experiment showed that microwaves could heat foods quickly. Spencer's discovery eventually led to the development of the microwave oven—an appliance found in many kitchens today.

Math ACTIVITY

Popcorn pops when the inside of the kernel reaches a temperature of about 175°C. Convert this temperature to degrees Fahrenheit.

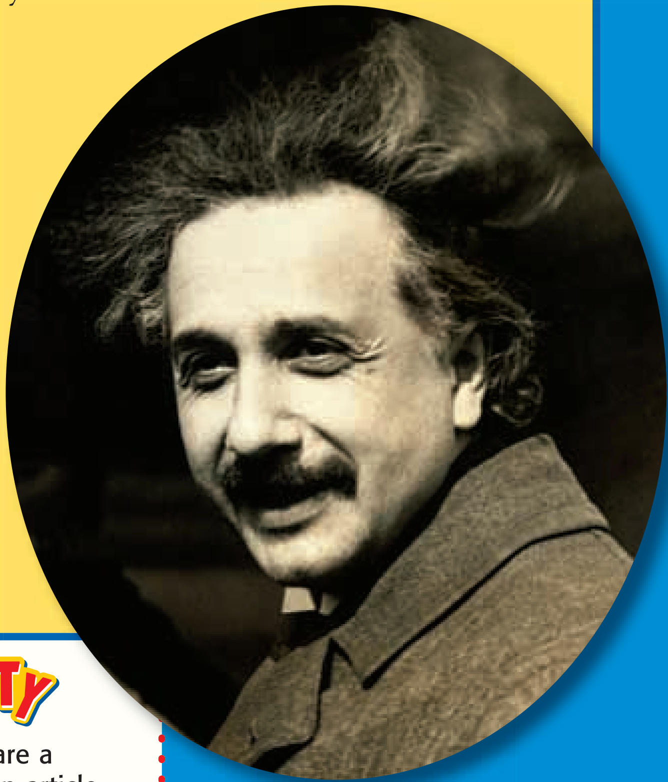
Copyright © by Holt, Rinehart and Winston. All rights reserved.

People in Science

Albert Einstein

A Light Pioneer When Albert Einstein was 15 years old, he asked himself, "What would the world look like if I were speeding along on a motorcycle at the speed of light?" For many years afterward, he would think about this question and about the very nature of light, time, space, and matter. He even questioned the ideas of Isaac Newton, which had been widely accepted for 200 years. Einstein was bold. And he was able to see the universe in a totally new way.

In 1905, Einstein published a paper on the nature of light. He knew from the earlier experiments of others that light was a wavelike phenomenon. But he theorized that light could also travel as particles. Scientists did not readily accept Einstein's particle theory of light. Even 10 years later, the American physicist Robert Millikan, who proved that the particle theory of light was true, was reluctant to believe his own experimental results. Einstein's theory helped pave the way for television, computers, and other important technologies. The theory also earned Einstein a Nobel Prize in physics in 1921.



Language Arts ACTIVITY

WRITING SKILL Imagine that it is 1921. You are a newspaper reporter writing an article about Albert Einstein and his Nobel Prize. Write a one-page article about Albert Einstein, his theory, and the award he won.

go.hrw.com

To learn more about these Science in Action topics, visit **go.hrw.com** and type in the keyword **HP5LGTF.**

Current Science

Check out Current Science® articles related to this chapter by visiting go.hrw.com. Just type in the keyword HP5CS22.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

UNIT 6

TIMELINE

Populations and the Environment

What did you have for breakfast this morning? Your breakfast was a result of living things working together. For example, milk comes from a cow. The cow eats plants to gain energy. Bacteria help the plants obtain nutrients from the soil. And the soil has nutrients because fungi break down dead trees.

All living things on Earth are interconnected. In this unit, you will learn about the interaction of living things. This timeline shows some of the ways that humans have studied and affected the Earth.

1661

John Evelyn publishes a book condemning air pollution in London, England.

1771

In his experiments with plants, Joseph Priestley finds that plants use carbon dioxide and release oxygen.

1933

The Civilian Conservation Corps is established. The corps plants trees, fights forest fires, and builds dams to control floods.

1990

To save dolphins from being caught in fishing nets, U.S. tuna processors announce that they will not accept tuna caught in nets that can kill dolphins.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

1851

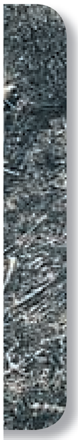
The United States imports sparrows from Germany to defend against crop-damaging caterpillars.

1854

Henry David Thoreau's *Walden* is published. In it, Thoreau asserts that people should live in harmony with nature.

1872

The first U.S. national park, Yellowstone, is established by Congress.



1962

Rachel Carson's book *Silent Spring,* which describes the wasteful use of pesticides and their destruction of the environment, is published.

1970

The Environmental Protection Agency (EPA) is formed to set and enforce pollution-control standards in the United States.

1973

The United States Congress passes the Endangered Species Act.

1993

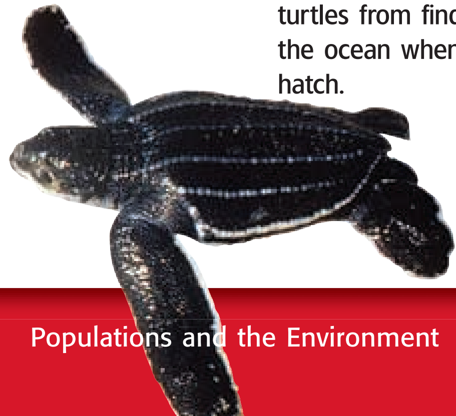
Americans recycle 59.5 billion aluminum cans (two out of every three cans).

1996

The Glen Canyon Dam is opened, purposefully flooding the Grand Canyon. The flooding helps maintain the ecological balance by restoring beaches and sandbars and rejuvenating marshes.

2002

The U.S. Fish and Wildlife Service installs red neon lights along the Florida coast to replace lights that distract baby sea turtles from finding the ocean when they hatch.



Copyright © by Holt, Rinehart and Winston. All rights reserved.

18

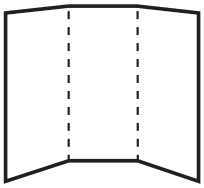
Interactions of Living Things

About the PHOTO

A chameleon is about to use its long tongue to grab an insect. A chameleon's body can change color to match its surroundings. Blending helps the chameleon sneak up on its prey and keeps the chameleon safe from animals that would like to make a snack out of a chameleon.

PRE-READING ACTIVITY

FOLDNOTES **Tri-Fold** Before you read the chapter, create the FoldNote entitled "Tri-Fold" described in the **Study Skills** section of the Appendix. Write what you know about the interactions of living things in the column labeled "Know." Then, write what you want to know in the column labeled "Want." As you read the chapter, write what you learn about the interactions of living things in the column labeled "Learn."



Copyright © by Holt, Rinehart and Winston. All rights reserved.

START-UP ACTIVITY

Who Eats Whom?

In this activity, you will learn how organisms interact when finding (or becoming) the next meal.

Procedure

1. On each of **five index cards,** print the name of one of the following organisms: killer whale, cod fish, krill shrimp, algae, and leopard seal.
2. On your desk, arrange the cards in a chain to show who eats whom.
3. Record the order of your cards.
4. In nature, would you expect to see more killer whales or cod? Arrange the cards in order of most individuals in an organism group to fewest.

Analysis

1. What might happen to the other organisms if algae were removed from this group? What might happen if the killer whales were removed?
2. Are there any organisms in this group that eat more than one kind of food? (Hint: What else might a seal, a fish, or a killer whale eat?) How could you change the order of your cards to show this information? How could you use pieces of string to show these relationships?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 1

Everything Is Connected

An alligator drifts in a weedy Florida river, watching a long, thin fish called a gar. *The gar swims too close to the alligator. Then, in a rush of murky water, the alligator swallows the gar whole and slowly swims away.*

It is clear that two organisms have interacted when one eats the other. But organisms have many interactions other than simply “who eats whom.” For example, alligators dig underwater holes to escape from the heat. After the alligators abandon these holes, fish live in the holes during the winter dry period.

READING WARM-UP

Objectives

- Distinguish between the biotic and abiotic parts of the environment.
- Explain how populations and communities are related.
- Describe how the abiotic parts of the environment affect ecosystems.

Terms to Learn

ecology
biotic
abiotic
population
community
ecosystem
biosphere

READING STRATEGY

Reading Organizer As you read this section, create an outline of the section. Use the headings from the section in your outline.

Studying the Web of Life

All living things are connected in a web of life. Scientists who study the web of life specialize in the science of ecology. **Ecology** is the study of the interactions of organisms with one another and with their environment.

The Two Parts of an Environment

An organism’s environment consists of all of the things that affect the organism. These things can be divided into two groups. All of the organisms that live together and interact with each other make up the **biotic** part of the environment. The **abiotic** part of the environment consists of the nonliving factors, such as water, soil, light, and temperature. Water, oxygen, and other substances cycle between the biotic parts and the abiotic parts of an ecosystem. How many biotic parts and abiotic parts do you see in **Figure 1**?

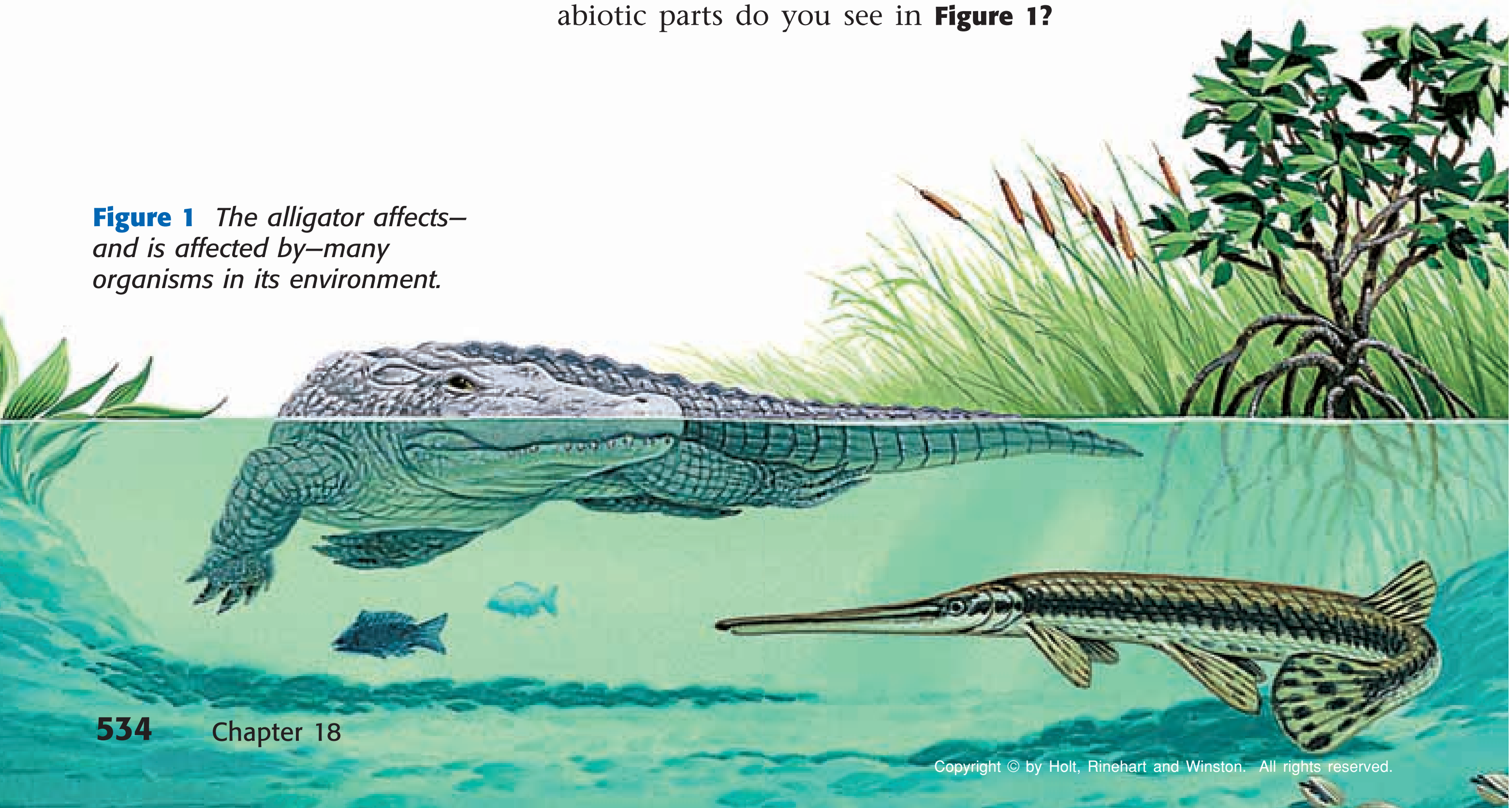


Figure 1 *The alligator affects—and is affected by—many organisms in its environment.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Organization in the Environment

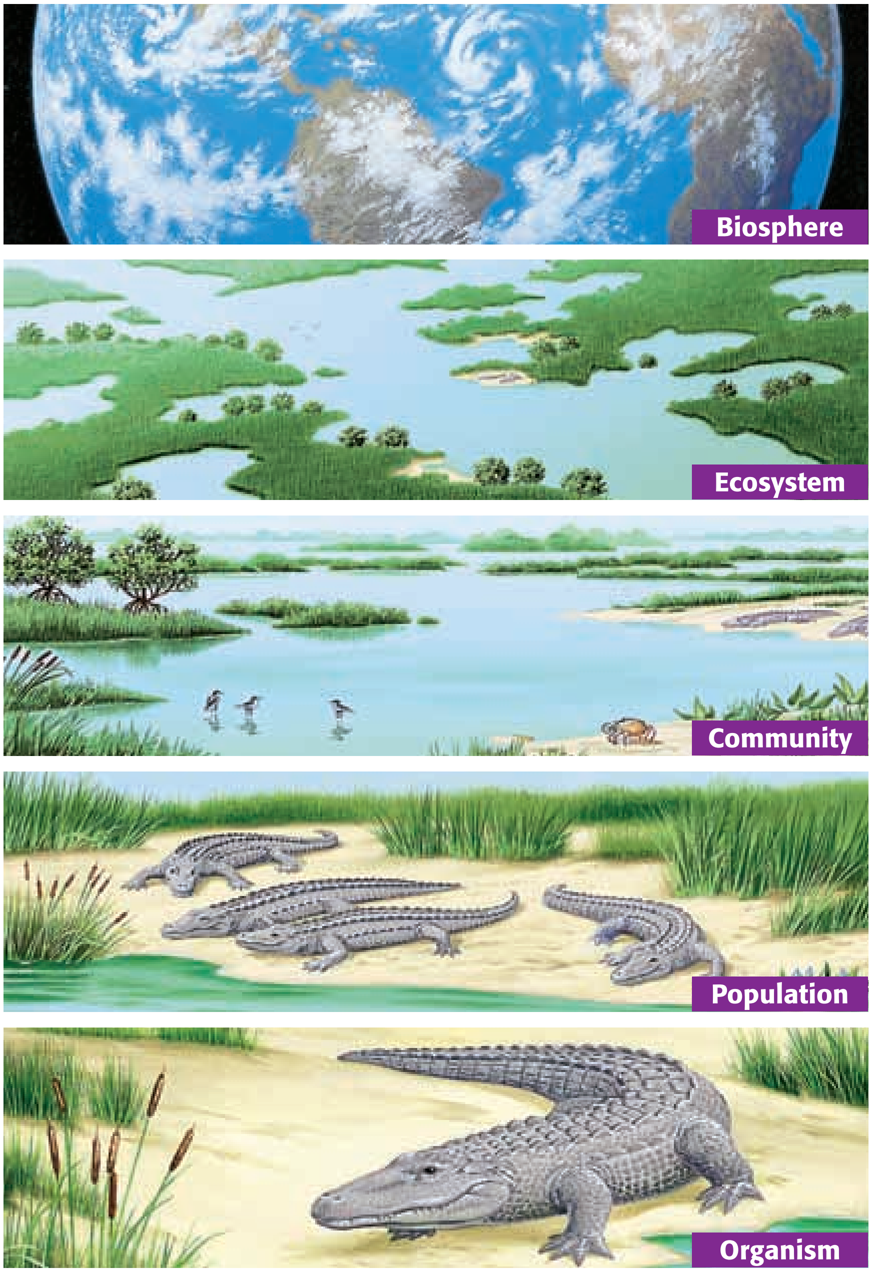
At first glance, the environment may seem disorganized. However, the environment can be arranged into different levels, as shown in **Figure 2.** The first level is made of an individual organism. The second level is larger and is made of similar organisms, which form a population. The third level is made of different populations, which form a community. The fourth level is made of a community and its abiotic environment, which form an ecosystem. The fifth and final level contains all ecosystems, which form the biosphere.

ecology the study of the interactions of living organisms with one another and with their environment

biotic describes living factors in the environment

abiotic describes the nonliving part of the environment, including water, rocks, light, and temperature

Figure 2 **The Five Levels of Environmental Organization**



Quick Lab

Meeting the Neighbors

1. Explore two or three blocks of your neighborhood.
2. Draw a map of the area's biotic and abiotic features. For example, map the location of sidewalks, large rocks, trees, water features, and any animals you see. Remember to approach all plants and animals with caution. Use your map to answer the following questions.
3. How are the biotic factors affected by the abiotic factors?
4. How are the abiotic factors affected by the biotic factors?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Populations

A salt marsh, such as the one shown in **Figure 3,** is a coastal area where grasslike plants grow. Within the salt marsh are animals. Each animal is a part of a **population,** or a group of individuals of the same species that live together. For example, all of the seaside sparrows that live in the same salt marsh are members of a population. The individuals in the population often compete with one another for food, nesting space, and mates.

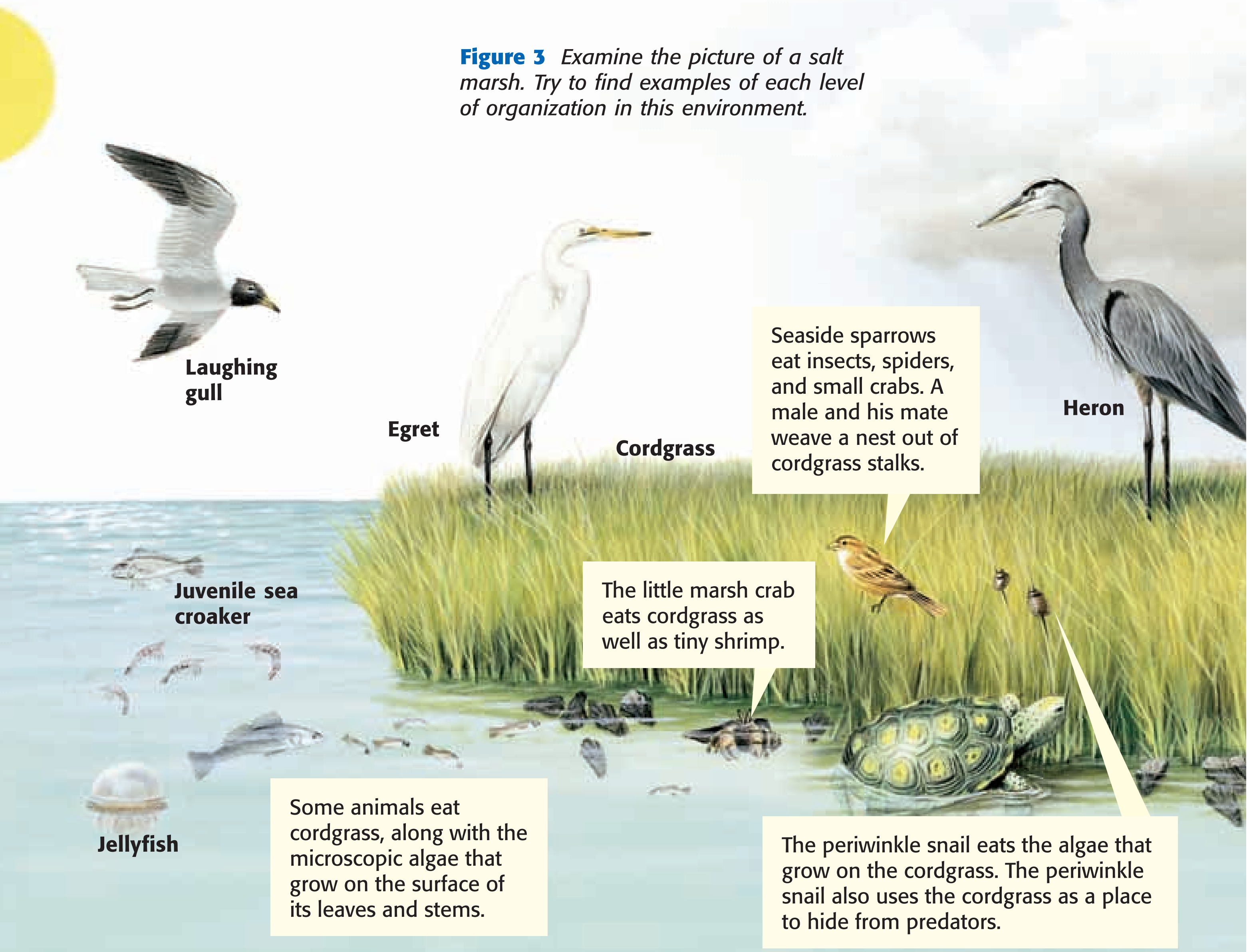
population a group of organisms of the same species that live in a specific geographical area

community all the populations of species that live in the same habitat and interact with each other

Communities

A **community** consists of all of the populations of species that live and interact in an area. The animals and plants in **Figure 3** form a salt-marsh community. The populations in a community depend on each other for food, shelter, and many other things.

Figure 3 *Examine the picture of a salt marsh. Try to find examples of each level of organization in this environment.*



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Ecosystems

An **ecosystem** is made up of a community of organisms and the abiotic environment of the community. An ecologist studying the ecosystem could examine how organisms interact as well as how temperature, precipitation, and soil characteristics affect the organisms. For example, the rivers that empty into the salt marsh carry nutrients, such as nitrogen, from the land. These nutrients affect the growth of the cordgrass and algae.

ecosystem a community of organisms and their abiotic environment

biosphere the part of Earth where life exists

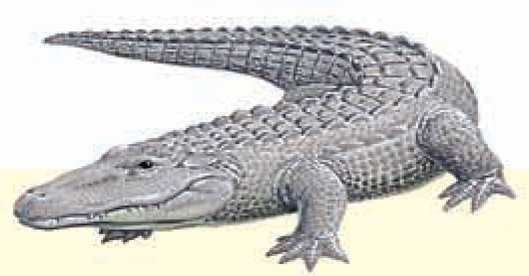
The Biosphere

The **biosphere** is the part of Earth where life exists. It extends from the deepest parts of the ocean to high in the air where plant spores drift. Ecologists study the biosphere to learn how organisms interact with the abiotic environment—Earth's atmosphere, water, soil, and rock. The water in the abiotic environment includes fresh water and salt water as well as water that is frozen in polar icecaps and glaciers.

INTERNET ACTIVITY

For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HL5INTW.**

Reading Check **What is the biosphere?** (*See the Appendix for answers to Reading Checks.*)



SECTION Review

Summary

- All living things are connected in a web of life.
- The biotic part of an environment is made up of all of the living things found within that environment.
- The abiotic part of an environment is made up of all of the nonliving things found within that environment, such as water and light.
- An ecosystem is made up of a community of organisms and its abiotic environment.

Using Key Terms

1. In your own words, write a definition for the term *ecology.*
2. Use the following terms in the same sentence: *biotic* and *abiotic*.

Understanding Key Ideas

3. Which of the following is the highest level of environmental organization?
   a. ecosystem **c.** population
   b. community **d.** organism
4. What makes up a community?
5. Give two examples of how abiotic factors can affect an ecosystem.

Math Skills

6. From sea level, the biosphere goes up about 9 km and down about 19 km. What is the thickness of the biosphere in meters?

Critical Thinking

7. **Analyzing Relationships** What would happen to the other organisms in the salt-marsh ecosystem if the cordgrass suddenly died?
8. **Identifying Relationships** Explain in your own words what people mean when they say that everything is connected.
9. **Analyzing Ideas** Do ecosystems have borders? Explain your answer.

SCILINKS® NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Biotic and Abiotic Factors; Organization in the Environment

SciLinks code: HSM0164; HSM1079

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 2

Living Things Need Energy

Do you think you could survive on only water and vitamins? Eating food satisfies your hunger because it provides something you cannot live without—energy.

READING WARM-UP

Objectives

- Describe the functions of producers, consumers, and decomposers in an ecosystem.
- Distinguish between a food chain and a food web.
- Explain how energy flows through a food web.
- Describe how the removal of one species affects the entire food web.

Terms to Learn

herbivore	food chain
carnivore	food web
omnivore	energy pyramid

READING STRATEGY

Reading Organizer As you read this section, make a table comparing producers, consumers, and decomposers.

Living things need energy to survive. For example, black-tailed prairie dogs, which live in the grasslands of North America, eat grass and seeds to get the energy they need. Everything a prairie dog does requires energy. The same is true for the plants that grow in the grasslands where the prairie dogs live.

The Energy Connection

Organisms, in a prairie or any community, can be divided into three groups based on how they get energy. These groups are producers, consumers, and decomposers. Examine **Figure 1** to see how energy passes through an ecosystem.

Producers

Organisms that use sunlight directly to make food are called *producers*. They do this by using a process called *photosynthesis*. Most producers are plants, but algae and some bacteria are also producers. Grasses are the main producers in a prairie ecosystem. Examples of producers in other ecosystems include cordgrass and algae in a salt marsh and trees in a forest. Algae are the main producers in the ocean.

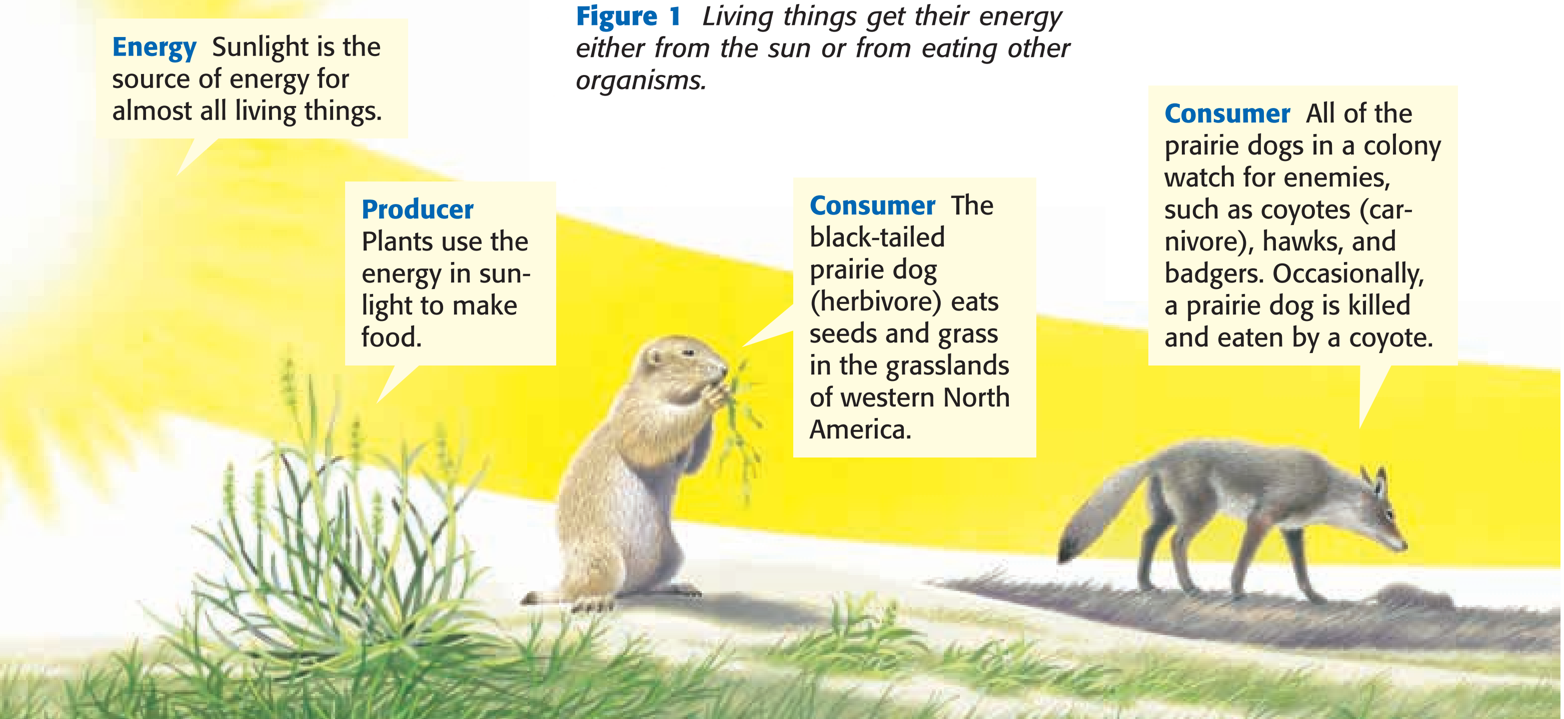


Figure 1 *Living things get their energy either from the sun or from eating other organisms.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Consumers

Organisms that eat other organisms are called *consumers*. They cannot use the sun's energy to make food like producers can. Instead, consumers eat producers or other animals to obtain energy. There are several kinds of consumers. A consumer that eats only plants is called a **herbivore.** Herbivores found in the prairie include grasshoppers, prairie dogs, and bison. A **carnivore** is a consumer that eats animals. Carnivores in the prairie include coyotes, hawks, badgers, and owls. Consumers known as **omnivores** eat both plants and animals. The grasshopper mouse is an example of an omnivore. It eats insects, lizards, and grass seeds.

Scavengers are omnivores that eat dead plants and animals. The turkey vulture is a scavenger in the prairie. A vulture will eat what is left after a coyote has killed and eaten an animal. Scavengers also eat animals and plants that have died from natural causes.

Reading Check **What are organisms that eat other organisms called?** (*See the Appendix for answers to Reading Checks.*)

herbivore an organism that eats only plants

carnivore an organism that eats animals

omnivore an organism that eats both plants and animals

Decomposers

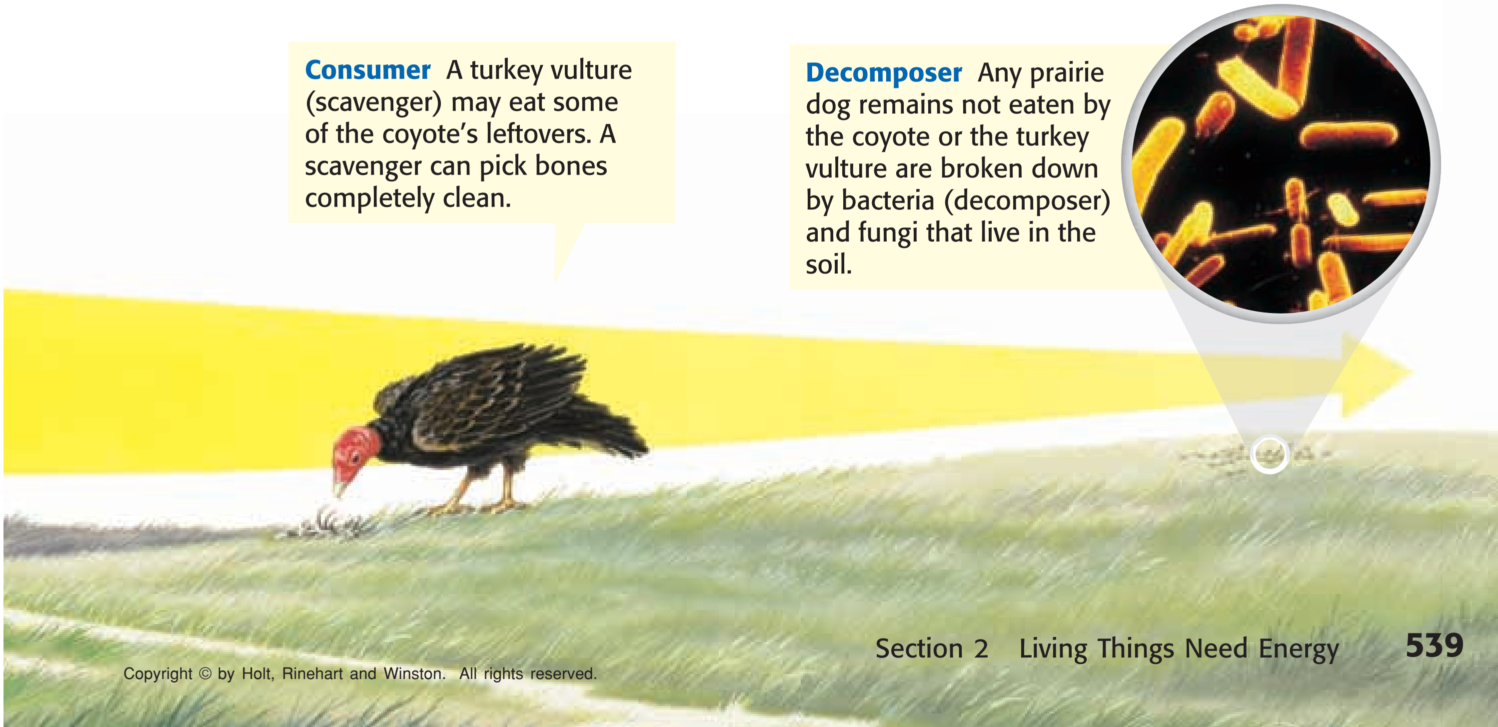
Organisms that get energy by breaking down dead organisms are called *decomposers*. Bacteria and fungi are decomposers. These organisms remove stored energy from dead organisms. They produce simple materials, such as water and carbon dioxide, which can be used by other living things. Decomposers are important because they are nature's recyclers.

SCHOOL to HOME

A Chain Game

With the help of your parent, make a list of the foods you ate at your most recent meal. Trace the energy of each food back to the sun. Which foods on your list were consumers? How many were producers?

ACTIVITY



Consumer A turkey vulture (scavenger) may eat some of the coyote's leftovers. A scavenger can pick bones completely clean.

Decomposer Any prairie dog remains not eaten by the coyote or the turkey vulture are broken down by bacteria (decomposer) and fungi that live in the soil.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

food chain the pathway of energy transfer through various stages as a result of the feeding patterns of a series of organisms

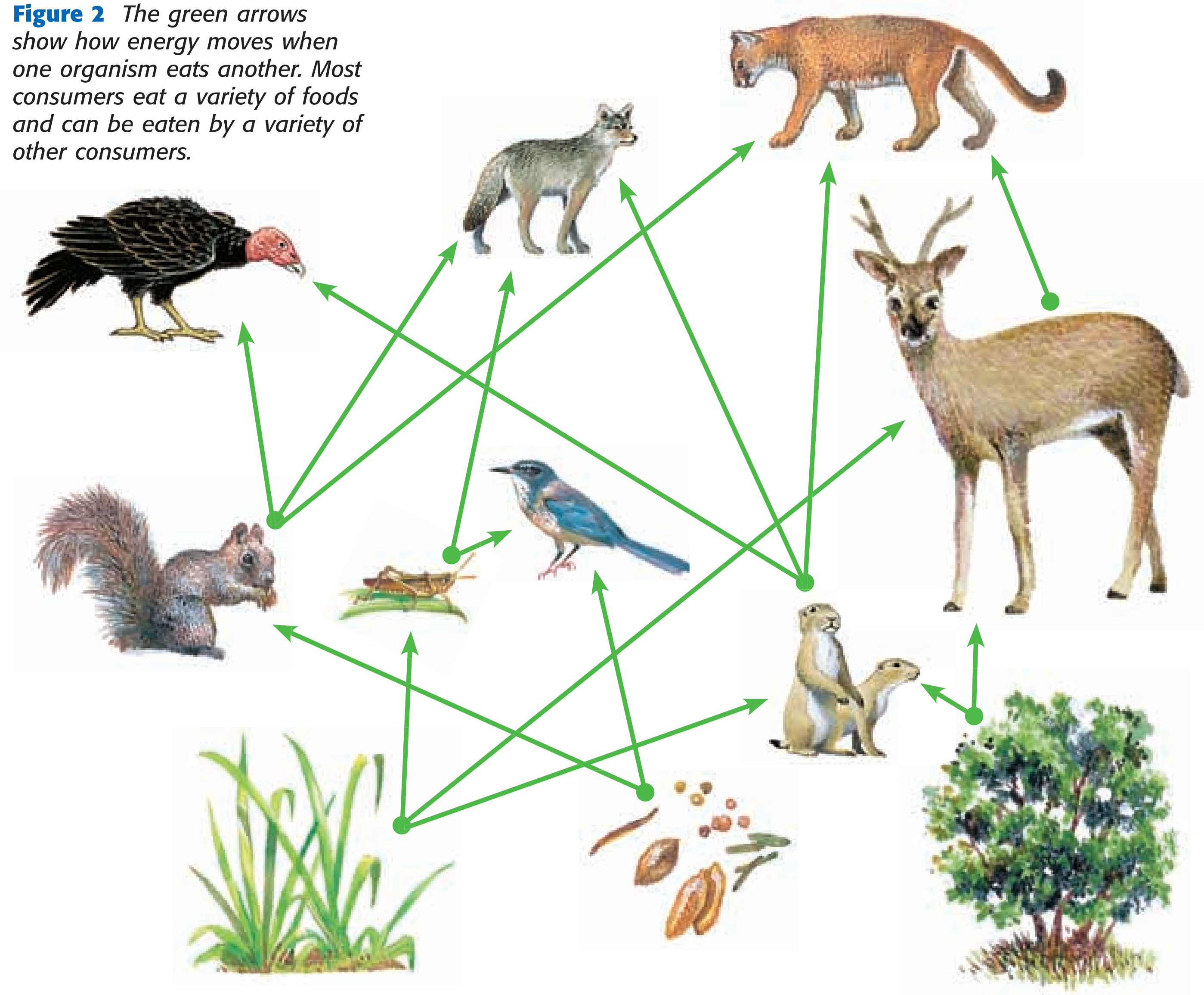
food web a diagram that shows the feeding relationships between organisms in an ecosystem

Food Chains and Food Webs

Figure 1 on the previous page, shows a food chain. A **food chain** is a diagram that shows how energy in food flows from one organism to another. Because few organisms eat just one kind of food, simple food chains are rare.

The energy connections in nature are more accurately shown by a food web than by a food chain. A **food web** is a diagram that shows the feeding relationships between organisms in an ecosystem. A food web shows how matter and energy are transferred between organisms. **Figure 2** shows a simple food web. The arrow going from the prairie dog to the coyote shows that the prairie dog is food for the coyote. Energy moves in a one-way direction, even in a food web. Any energy that is not immediately used by an organism is stored in the organism's tissues. Only the energy stored in its tissues can be used by the next consumer. There are two main food webs on Earth: a land food web and an aquatic food web.

Figure 2 *The green arrows show how energy moves when one organism eats another. Most consumers eat a variety of foods and can be eaten by a variety of other consumers.*



Copyright © by Holt, Rinehart and Winston. All rights reserved.

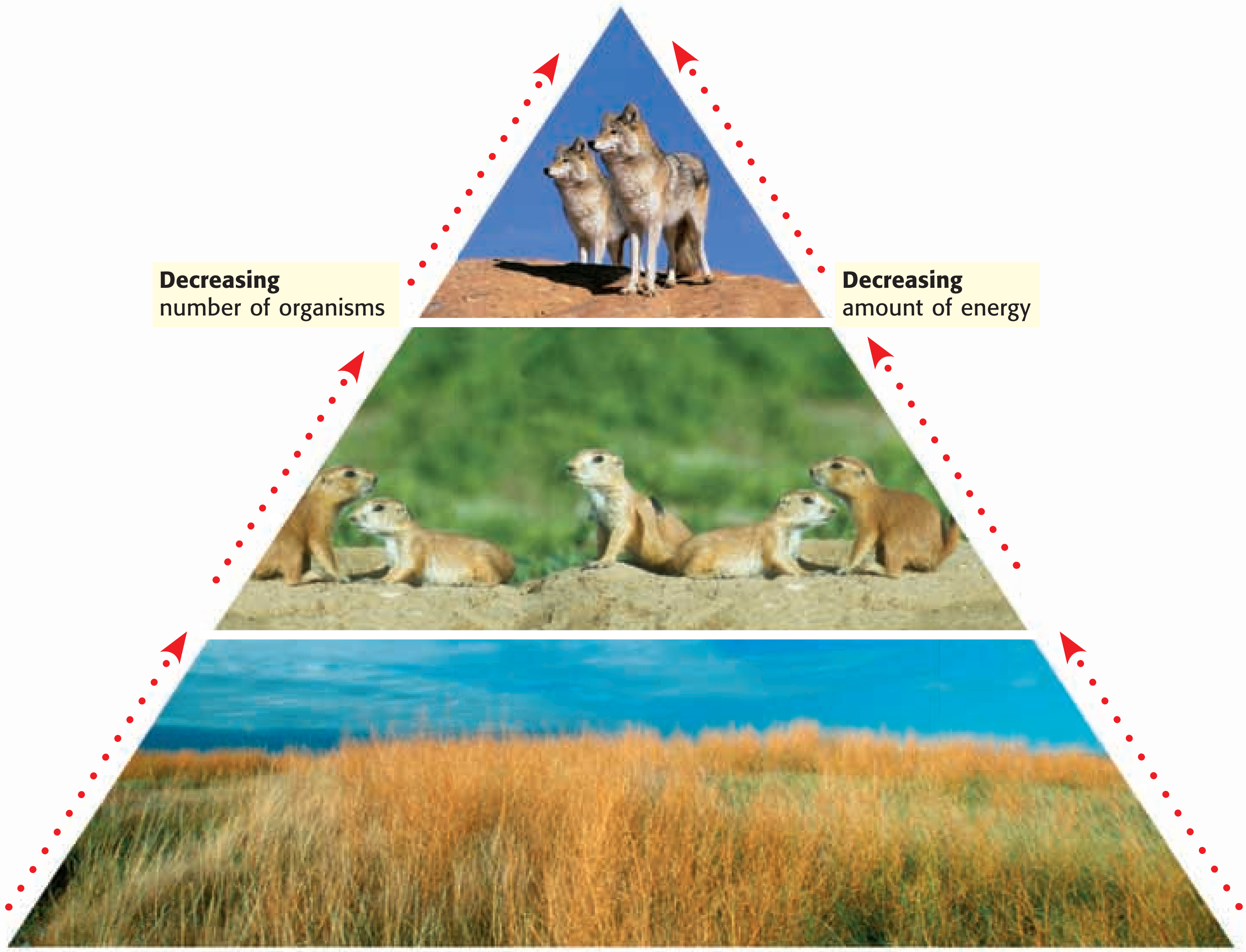


Figure 3 *The pyramid represents energy. As you can see, more energy is available at the base of the pyramid than at its top.*

Energy Pyramids

Grass uses most of the energy it gets from sunlight for its own life processes. But some of the energy is stored in the tissues of the grass. This energy is used by the prairie dogs and other animals that eat the grass. Prairie dogs use most of the energy that they get from eating grass and store only a little in their tissues. Therefore, a population of prairie dogs can support only a few coyotes. In the community, there must be more grass than prairie dogs and more prairie dogs than coyotes.

The energy at each level of the food chain can be seen in an energy pyramid. An **energy pyramid** is a diagram that shows an ecosystem's loss of energy. An example of an energy pyramid is shown in **Figure 3.** You can see that the energy pyramid has a large base and a small top. Less energy is available at higher levels because only energy stored in the tissues of an organism can be transferred to the next level.

energy pyramid a triangular diagram that shows an ecosystem's loss of energy, which results as energy passes through the ecosystem's food chain

Reading Check **What is an energy pyramid?**

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 4 *Organisms are affected when their habitat, the area in which they live, changes. As the wilderness was settled, the gray wolf population in the United States declined.*

Wolves and the Energy Pyramid

One species can be very important to the flow of energy in an environment. Gray wolves, which are shown in **Figure 4,** are consumers that control the populations of many other animals. The diet of gray wolves can include anything from a lizard to an elk. Because gray wolves are predators that prey on large animals, their place is at the top of the food pyramid.

Once common throughout much of the United States, gray wolves were almost wiped out as their habitat—the wilderness—was settled by humans. Without wolves, some species, such as elk, were no longer controlled. The overpopulation of elk affected the environment. In some areas, it led to overgrazing. The overgrazing left too little grass to support the elk and other populations who depended on grass for food. Soon, almost all of the populations in the area were affected by the loss of the gray wolves.

Reading Check **How were other animals affected by the disappearance of the gray wolf?**

Gray Wolves and the Food Web

Figure 5 *In small wolf packs, only one female has pups. The pups are cared for by all of the males and females in the pack.*

Gray wolves were brought back to Yellowstone National Park in 1995. The reintroduced wolves soon began to breed. **Figure 5** shows a wolf caring for pups. The U.S. Fish and Wildlife Service thinks the return of the wolves will restore the natural energy flow in the area, bring populations back into balance, and help restore the park's natural integrity.

Not everyone approves, however. Ranchers near Yellowstone are concerned about the safety of their livestock. Cows and sheep are not the natural prey of wolves. However, the wolves will eat cows and sheep if they are given the chance.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Balance in Ecosystems

As wolves become reestablished in Yellowstone National Park, they kill the old, injured, and diseased elk. This process is reducing the number of elk. The smaller elk population is letting more plants grow. So, the numbers of animals that eat the plants, such as snowshoe hares, and the animals that eat the hares, such as foxes, are increasing.

All organisms in a food web are important for the health and balance of all other organisms in the food web. But the debate over the introduction of wolves to Yellowstone National Park will most likely continue for years to come.

MATH PRACTICE

Energy Pyramids

Draw an energy pyramid for a river ecosystem that contains four levels—aquatic plants, insect larvae, bluegill fish, and a largemouth bass. The plants obtain 10,000 units of energy from sunlight. If each level uses 90% of the energy it receives from the previous level, how many units of energy are available to the bass?

SECTION Review

Summary

- Producers use the energy in sunlight to make their own food.
- Consumers eat producers and other organisms to gain energy.
- Food chains represent how energy flows from one organism to another.
- All organisms are important to maintain the balance of energy in the food web.
- Energy pyramids show how energy is lost at each food chain level.

Using Key Terms

1. Use each of the following terms in a separate sentence: *herbivores, carnivores,* and *omnivores*.
2. In your own words, write a definition for each of the following terms: *food chain, food web,* and *energy pyramid*.

Understanding Key Ideas

3. Herbivores, carnivores, and scavengers are all examples of
   a. producers.
   b. decomposers.
   c. consumers.
   d. omnivores.
4. Explain the importance of decomposers in an ecosystem.
5. Describe how producers, consumers, and decomposers are linked in a food chain.
6. Describe how energy flows through a food web.

Math Skills

7. The plants in each square meter of an ecosystem obtained 20,810 Calories of energy from sunlight per year. The herbivores in that ecosystem ate all the plants but obtained only 3,370 Calories of energy. How much energy did the plants use?

Critical Thinking

8. **Identifying Relationships** Draw two food chains, and depict how they link together to form a food web.
9. **Applying Concepts** Are consumers found at the top or bottom of an energy pyramid? Explain your answer.
10. **Predicting Consequences** What would happen if a species disappeared from an ecosystem?

SCILINKS® NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Food Chains and Food Webs
SciLinks code: HSM0594

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 3

Types of Interactions

Look at the seaweed forest shown in **Figure 1** *below. How many fish do you see? How many seaweed plants do you count? Why do you think there are more members of the seaweed population than members of the fish population?*

In natural communities, the sizes of populations of different organisms can vary greatly. This variation happens because everything in the environment affects every other thing. Populations also affect every other population.

Interactions with the Environment

Most living things produce more offspring than will survive. A female frog, for example, might lay hundreds of eggs in a small pond. In a few months, the population of frogs in that pond will be about the same as it was the year before. Why won't the pond become overrun with frogs? An organism, such as a frog, interacts with biotic and abiotic factors in its environment that can control the size of its population.

Limiting Factors

Populations cannot grow without stopping, because the environment contains a limited amount of food, water, living space, and other resources. A resource that is so scarce that it limits the size of a population is called a *limiting factor*. For example, food becomes a limiting factor when a population becomes too large for the amount of food available. Any single resource can be a limiting factor to a population's size.

READING WARM-UP

Objectives

- Explain the relationship between carrying capacity and limiting factors.
- Describe the two types of competition.
- Distinguish between mutualism, commensalism, and parasitism. Give an example of coevolution.

Terms to Learn

carrying capacity	mutualism
prey	commensalism
predator	parasitism
symbiosis	coevolution

READING STRATEGY

Reading Organizer As you read this section, make a concept map by using the terms above.

Figure 1 *This seaweed forest is home to a large number of interacting species.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Carrying Capacity

The largest population that an environment can support is known as the **carrying capacity.** When a population grows larger than its carrying capacity, limiting factors in the environment cause individuals to die off or leave. As individuals die or leave, the population decreases.

For example, after a rainy season, plants may produce a large crop of leaves and seeds. This large amount of food may cause an herbivore population to grow. If the next year has less rainfall, there won't be enough food to support the large herbivore population. In this way, a population may become larger than the carrying capacity, but only for a little while. A limiting factor will cause the population to return to a size that the environment can support.

carrying capacity the largest population that an environment can support at any given time

Interactions Between Organisms

Populations contain individuals of a single species that interact with each other. For example, a group of rabbits feeding in the same area is a population. Rabbits will cooperate with each other by warning the entire group of danger. Communities contain interacting populations. For example, a coral reef that contains many species of corals trying to find living space is a community. Ecologists have described four main ways that species and individuals affect each other: competition, predators and prey, symbiotic relationships, and coevolution.

Reading Check **What are four main ways that organisms affect one another?** (*See the Appendix for answers to Reading Checks.*)

Competition

Some populations can share resources. These populations are said to *coexist* with one another. However, when two or more individuals or populations try to use the same resource, such as food, water, shelter, or sunlight, *competition* exists. Because resources are in limited supply in the environment, their use by one individual or population decreases the amount available to other organisms.

Competition happens between individuals *within* a population. The elks in Yellowstone National Park are herbivores that compete with each other for the same food plants in the park. This competition is a big problem in winter, when many plants die.

Competition also happens *between* populations. The different species of trees in **Figure 2** are competing with each other for sunlight and space.

Figure 2 *Some of the trees in this forest grow tall to reach sunlight, which reduces the amount of sunlight available to shorter trees nearby.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Predators and Prey

prey an organism that is killed and eaten by another organism

predator an organism that eats all or part of another organism

Many interactions between species consist of the eating of one organism by another organism. The organism that is eaten is called the **prey.** The organism that eats the prey is called the **predator.** When a bird eats a worm, the worm is the prey and the bird is the predator.

Predator Adaptations

To survive, predators must be able to catch their prey. Predators have a wide variety of methods and abilities for doing so. The cheetah, for example, is able to run very quickly to catch its prey. The cheetah's speed gives it an advantage over other predators competing for the same prey.

Other predators, such as the goldenrod spider, shown in **Figure 3,** ambush their prey. The goldenrod spider blends in so well with the goldenrod flower that all it has to do is wait for its next insect meal to arrive.

Figure 3 *The goldenrod spider is difficult for its insect prey to see. Can you see it?*

Prey Adaptations

Prey have their own methods and abilities to keep from being eaten. Prey are able to run away, stay in groups, or camouflage themselves. Some prey are poisonous. They may advertise their poison with bright colors to warn predators to stay away. The fire salamander, shown in **Figure 4,** sprays a poison that burns. Predators quickly learn to recognize its *warning coloration.*

Many animals run away from predators. Prairie dogs run to their underground burrows when a predator approaches. Many small fishes, such as anchovies, swim in groups called *schools*. Antelopes and buffaloes stay in herds. All the eyes, ears, and noses of the individuals in the group are watching, listening, and smelling for predators. This behavior increases the likelihood of spotting a potential predator.

Figure 4 *Many predators know better than to eat the fire salamander! This colorful animal will make a predator very sick.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Camouflage

One way animals avoid being eaten is by being hard to see. A rabbit often freezes so that its natural color blends into a background of shrubs or grass. Blending in with the background is called *camouflage*. Many animals mimic twigs, leaves, stones, bark, or other materials in their environment. One insect, called a walking stick, looks just like a twig. Some walking sticks even sway a bit, as though a breeze were blowing.

Reading Check **What is camouflage, and how does it prevent an animal from being eaten?**

Defensive Chemicals

The spines of a porcupine clearly signal trouble to a potential predator, but other defenses may not be as obvious. Some animals defend themselves with chemicals. The skunk and the bombardier beetle both spray predators with irritating chemicals. Bees, ants, and wasps inject a powerful acid into their attackers. The skin of both the poison arrow frog and a bird called the *hooded pitohui* contains a deadly toxin. Any predator that eats, or tries to eat, one of these animals will likely die.

CONNECTION TO Environmental Science

Pretenders Some animals are pretenders. They don't have defensive chemicals. But they use warning coloration to their advantage. The Scarlet king snake has colored stripes that make it look like the poisonous coral snake. Even though the Scarlet king snake is harmless, predators see its bright colors and leave it alone. What might happen if there were more pretenders than there were animals with real defensive chemicals?

Warning Coloration

Animals that have a chemical defense need a way to warn predators that they should look elsewhere for a meal. Their chemical weapons are often advertised by warning colors, as shown in **Figure 5.** Predators will avoid any animal that has the colors and patterns they associate with pain, illness, or unpleasant experiences. The most common warning colors are bright shades of red, yellow, orange, black, and white.

Figure 5 *The warning coloration of the yellow jacket (left) and the pitohui (above) warns predators that they are dangerous.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Symbiosis

Some species have very close interactions with other species. **Symbiosis** is a close, long-term association between two or more species. The individuals in a symbiotic relationship can benefit from, be unaffected by, or be harmed by the relationship. Often, one species lives in or on the other species. The thousands of symbiotic relationships in nature are often classified into three groups: mutualism, commensalism, and parasitism.

symbiosis a relationship in which two different organisms live in close association with each other

mutualism a relationship between two species in which both species benefit

commensalism a relationship between two organisms in which one organism benefits and the other is unaffected

Mutualism

A symbiotic relationship in which both organisms benefit is called **mutualism** (MYOO choo uhl IZ uhm). For example, you and a species of bacteria that lives in your intestines benefit each other! The bacteria get food from you, and you get vitamins that the bacteria produce.

Another example of mutualism happens between corals and algae. Coral near the surface of the water provide a home for algae. The algae produce food for the coral by photosynthesis. The coral and algae are said to be *mutually dependent*. They depend on each other to live. **Figure 6** shows algae living inside the coral.

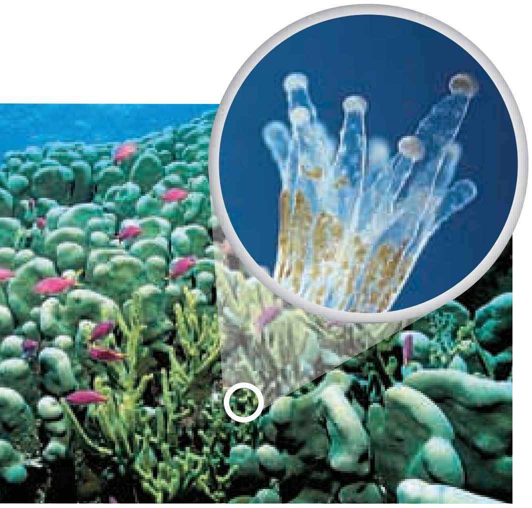


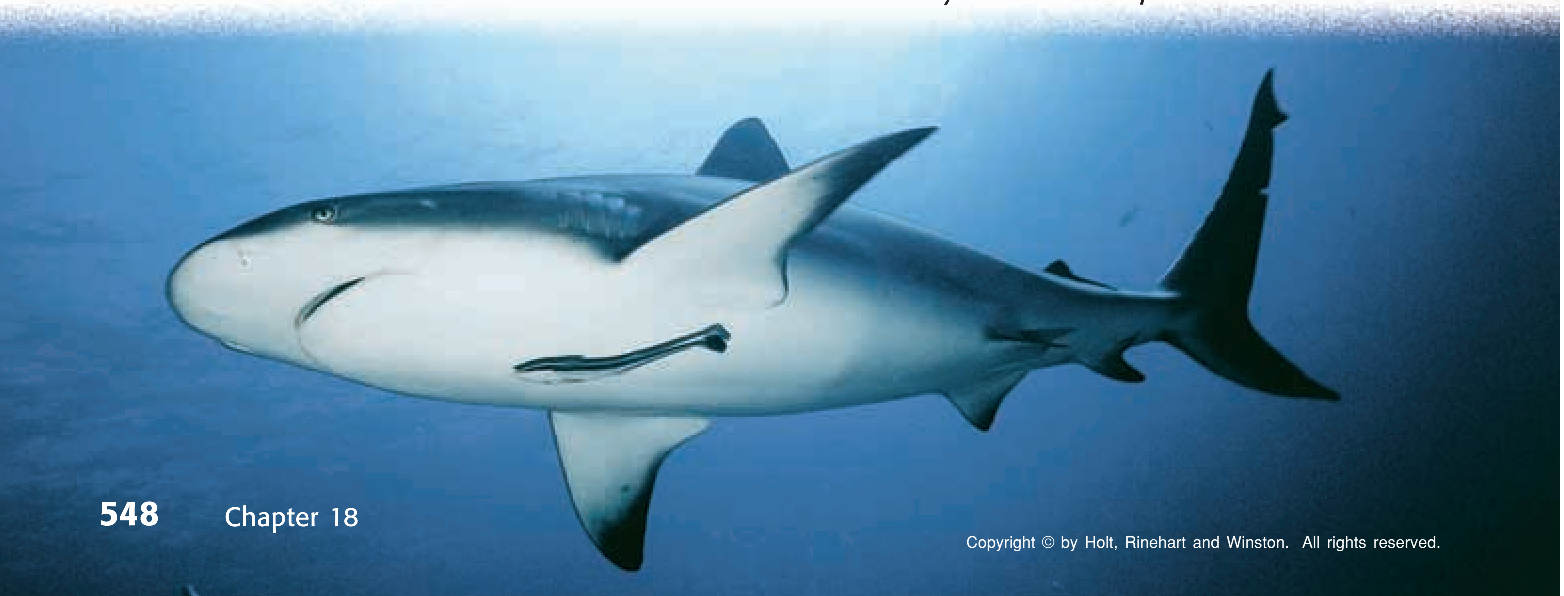
Figure 6 *In the smaller photo above, you can see the gold-colored algae inside the coral.*

Reading Check Which organism benefits in mutualism?

Commensalism

A symbiotic relationship in which one organism benefits and the other is unaffected is called **commensalism.** One example of commensalism is the relationship between sharks and smaller fish called *remoras*. **Figure 7** shows a shark with a remora attached to its body. Remoras "hitch a ride" and feed on scraps of food left by sharks. The remoras benefit from this relationship, while sharks are unaffected.

Figure 7 *The remora attached to the shark benefits from the relationship. The shark neither benefits from nor is harmed by the relationship.*



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 8 *The tomato hornworm is being parasitized by young wasps. Do you see their cocoons?*

Parasitism

A symbiotic association in which one organism benefits while the other is harmed is called **parasitism** (PAR uh SIT IZ uhm). The organism that benefits is called the *parasite*. The organism that is harmed is called the *host*. The parasite gets nourishment from its host while the host is weakened. Sometimes, a host dies. Parasites, such as ticks, live outside the host's body. Other parasites, such as tapeworms, live inside the host's body.

Figure 8 shows a bright green caterpillar called a *tomato hornworm*. A female wasp laid tiny eggs on the caterpillar. When the eggs hatch, each young wasp will burrow into the caterpillar's body. The young wasps will actually eat the caterpillar alive! In a short time, the caterpillar will be almost completely eaten and will die. When that happens, the adult wasps will fly away.

In this example of parasitism, the host dies. Most parasites, however, do not kill their hosts. Most parasites don't kill their hosts because parasites depend on their hosts. If a parasite were to kill its host, the parasite would have to find a new host.

parasitism a relationship between two species in which one species, the parasite, benefits from the other species, the host, which is harmed

coevolution the evolution of two species that is due to mutual influence, often in a way that makes the relationship more beneficial to both species

Coevolution

Relationships between organisms change over time. Interactions can also change the organisms themselves. When a long-term change takes place in two species because of their close interactions with one another, the change is called **coevolution.**

The ant and the acacia tree shown in **Figure 9** have a mutualistic relationship. The ants protect the tree by attacking other organisms that come near the tree. The tree has special structures that make food for the ants. The ants and the acacia tree may have coevolved through interactions between the two species. Coevolution can take place between any organisms that live close together. But changes happen over a very long period of time.

Figure 9 *Ants collect food made by the acacia tree and store the food in their shelter, which is also made by the tree.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Coevolution and Flowers

A *pollinator* is an organism that carries pollen from one flower to another. Pollination is necessary for reproduction in most plants.

Flowers have changed over millions of years to attract pollinators. Pollinators such as bees, bats, and hummingbirds can be attracted to a flower because of its color, odor, or nectar. Flowers pollinated by hummingbirds make nectar with the right amount of sugar for the bird. Hummingbirds have long beaks, which help them drink the nectar.

Some bats, such as the one shown in **Figure 10,** changed over time to have long, thin tongues and noses to help them reach the nectar in flowers. As the bat feeds on the nectar, its nose becomes covered with pollen. The next flower it eats from will be pollinated with the pollen it is gathering from this flower. The long nose helps it to feed and also makes it a better pollinator.

Because flowers and their pollinators have interacted so closely over millions of years, there are many examples of coevolution between them.

Reading Check **Why do flowers need to attract pollinators?**

Figure 10 *This bat is drinking nectar with its long, skinny tongue. The bat has coevolved with the flower over millions of years.*

CONNECTION TO Social Studies

Rabbits in Australia In 1859, settlers released 12 rabbits in Australia. There was plenty of food and no natural predators for the rabbits. The rabbit population increased so fast that the country was soon overrun by rabbits. Then, the Australian government introduced a rabbit virus to control the population. The first time the virus was used, more than 99% of the rabbits died. The survivors reproduced, and the rabbit population grew large again. The second time the virus was used, about 90% of the rabbits died. Once again, the rabbit population increased. The third time the virus was used, only about 50% of the rabbits died. Suggest what changes might have occurred in the rabbits and the virus.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION Review

Summary

- Limiting factors in the environment keep a population from growing without limit.
- Competition occurs when two or more individuals or populations try to use the same resource.
- A predator is an organism that eats all or part of another organism. The organism that is eaten is called *prey*.
- Prey have developed features such as camouflage, chemical defenses, and warning coloration to protect them from predators.
- Symbiosis occurs when two organisms form a very close relationship with one another over time.
- Close relationships over a very long time can result in coevolution. For example, flowers and their pollinators have evolved traits that benefit both.

Using Key Terms

1. In your own words, write a definition for the term *carrying capacity*.
2. Use each of the following terms in a separate sentence: *mutualism, commensalism,* and *parasitism*.

Understanding Key Ideas

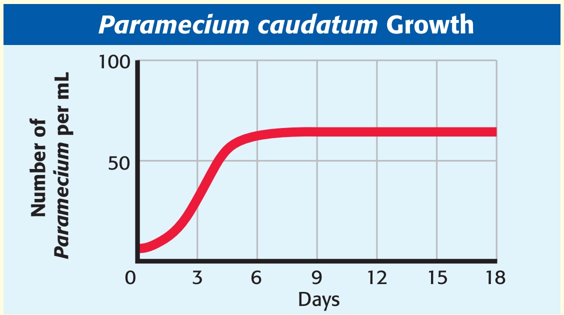
3. Which of the following is NOT a prey adaptation?
   a. camouflage
   b. chemical defenses
   c. warning coloration
   d. parasitism
4. Identify two things organisms compete with one another for.
5. Briefly describe one example of a predator-prey relationship. Identify the predator and the prey.

Critical Thinking

6. **Making Comparisons** Compare coevolution with symbiosis.
7. **Identifying Relationships** Explain the probable relationship between the giant *Rafflesia* flower, which smells like rotting meat, and the carrion flies that buzz around the flower. (Hint: *Carrion* means "rotting flesh.")
8. **Predicting Consequences** Predict what might happen if all of the ants were removed from an acacia tree.

Interpreting Graphics

The population graph below shows the growth of a species of the genus *Paramecium* (a single-celled microorganism) over 18 days. Food was added to the test tube occasionally. Use the graph below to answer the questions that follow.



9. What is the carrying capacity of the test tube as long as food is added?
10. Predict what will happen if no more food is added.
11. What keeps the number of paramecia at a steady level?

SCI LINKS® NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Predator/Prey; Coevolution
SciLinks code: HSM1205; HSM0309

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Skills Practice Lab

Capturing the Wild Bean

OBJECTIVES

Estimate the size of a "population" of beans.

Calculate the difference between your estimation and the actual number of beans.

MATERIALS

- bag, paper lunch, small
- beans, pinto
- calculator (optional)
- marker, permanent

When wildlife biologists study a group of organisms in an area, they need to know how many organisms live there. Sometimes, biologists worry that a certain organism is outgrowing the environment's carrying capacity. Other times, scientists need to know if an organism is becoming rare so that steps can be taken to protect it. However, animals can be difficult to count because they can move around and hide. Because of this challenge, biologists have developed methods to estimate the number of animals in a specific area. One of these counting methods is called the *mark-recapture method*.

In this activity, you will enter the territory of the wild pinto bean to estimate the number of beans that live in the paper-bag habitat.

Procedure

1. Prepare a data table like the one below.

Mark-Recapture Data Table

Number of animals in first capture	Total number of animals in recapture	Number of marked animals in recapture	Calculated estimate of population	Actual total population
	DO NOT WRITE IN BOOK			

2. Your teacher will provide you with a paper bag containing an unknown number of beans. Carefully reach into the bag, and remove a handful of beans.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

3. Count the number of beans you have "captured." Record this number in your data table under "Number of animals in first capture."
4. Use the permanent marker to carefully mark each bean that you have just counted. Allow the marks to dry completely. When all the marks are dry, place the marked beans back into the bag.
5. Gently mix the beans in the bag so that the marks won't rub off. Once again, reach into the bag. "Capture" and remove a handful of beans.
6. Count the number of beans in your "recapture." Record this number in your data table under "Total number of animals in recapture."
7. Count the beans in your recapture that have marks from the first capture. Record this number in your data table under "Number of marked animals in recapture."
8. Calculate your estimation of the total number of beans in the bag by using the following equation:

$$\frac{\text{number of beans in recapture} \times \text{number of beans marked}}{\text{number of marked beans in recapture}} = \text{calculated estimate of population}$$

   Enter this number in your data table under "Calculated estimate of population."
9. Place all the beans in the bag. Then empty the bag on your work table. Be careful that no beans escape! Count each bean as you place them one at a time back into the bag. Record the number in your data table under "Actual total population."

Analyze the Results

1. **Evaluating Results** How close was your estimate to the actual number of beans?

Draw Conclusions

2. **Evaluating Methods** If your estimate was not close to the actual number of beans, how might you change your mark-recapture procedure? If you did not recapture any marked beans, what might be the cause?

Applying Your Data

How could you use the mark-recapture method to estimate the population of turtles in a small pond? Explain your procedure.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Chapter Review

USING KEY TERMS

1. Use each of the following terms in a separate sentence: *symbiosis, mutualism, commensalism,* and *parasitism.*

Complete each of the following sentences by choosing the correct term from the word bank.

biotic	abiotic
ecosystem	community

2. The environment includes _____ factors, including water, rocks, and light.
3. The environment also includes _____, or living, factors.
4. A community of organisms and their environment is called a(n) _____.

For each pair of terms, explain how the meanings of the terms differ.

5. *community* and *population*
6. *ecosystem* and *biosphere*
7. *producers* and *consumers*

UNDERSTANDING KEY IDEAS

Multiple Choice

8. A tick sucks blood from a dog. In this relationship, the tick is the _____ and the dog is the _____.
   - **a.** parasite, prey
   - **b.** predator, host
   - **c.** parasite, host
   - **d.** host, parasite
9. Resources such as water, food, or sunlight are likely to be limiting factors
   - **a.** when population size is decreasing.
   - **b.** when predators eat their prey.
   - **c.** when the population is small.
   - **d.** when a population is approaching the carrying capacity.
10. Nature's recyclers are
    - **a.** predators.
    - **b.** decomposers.
    - **c.** producers.
    - **d.** omnivores.
11. A beneficial association between coral and algae is an example of
    - **a.** commensalism.
    - **b.** parasitism.
    - **c.** mutualism.
    - **d.** predation.
12. The process by which energy moves through an ecosystem can be represented by
    - **a.** food chains.
    - **b.** energy pyramids.
    - **c.** food webs.
    - **d.** All of the above
13. Which organisms does the base of an energy pyramid represent?
    - **a.** producers
    - **b.** carnivores
    - **c.** herbivores
    - **d.** scavengers
14. Which of the following shows the correct order in a food chain?
    - **a.** sun→producers→herbivores→scavengers→carnivores
    - **b.** sun→consumers→predators→parasites→hosts
    - **c.** sun→producers→decomposers→consumers→omnivores
    - **d.** sun→producers→herbivores→carnivores→scavengers

Copyright © by Holt, Rinehart and Winston. All rights reserved.

15. Remoras and sharks have a relationship that is best described as
    a. mutualism.
    b. commensalism.
    c. predator and prey.
    d. parasitism.

Short Answer

16. Describe how energy flows through a food web.

17. Explain how the food web changed when the gray wolf disappeared from Yellowstone National Park.

18. How are the competition between two trees of the same species and the competition between two different species of trees similar?

19. How do limiting factors affect the carrying capacity of an environment?

20. What is coevolution?

CRITICAL THINKING

21. **Concept Mapping** Use the following terms to create a concept map: *herbivores, organisms, producers, populations, ecosystems, consumers, communities, carnivores,* and *biosphere*.

22. **Identifying Relationships** Could a balanced ecosystem contain producers and consumers but not decomposers? Why or why not?

23. **Predicting Consequences** Some biologists think that certain species, such as alligators and wolves, help maintain biological diversity in their ecosystems. Predict what might happen to other organisms, such as gar fish or herons, if alligators became extinct in the Florida Everglades.

24. **Expressing Opinions** Do you think there is a carrying capacity for humans? Why or why not?

INTERPRETING GRAPHICS

Use the energy pyramid below to answer the questions that follow.

25. According to the energy pyramid, are there more prairie dogs than plants, or are there more plants than prairie dogs?

26. What level has the most energy?

27. Would an energy pyramid such as this one exist in nature?

28. How could you change this pyramid to look like one representing a real ecosystem?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Standardized Test Preparation

EOG Prep

READING

Read each of the passages below. Then, answer the questions that follow each passage.

Passage 1 Two or more individuals trying to use the same resource, such as food, water, shelter, space, or sunlight is called *competition*. Because resources are in limited supply in the environment, the use of them by one individual or population decreases the amount available to other organisms. Competition also occurs between individuals within a population. The elk in Yellowstone National Park are herbivores that compete with each other for the same food plants in the park.

1. According to the passage, competition occurs between which of the following?

- **A** individuals trying to use the same resource
- **B** elk and carnivores
- **C** food and shelter
- **D** individuals trying to use different resources

2. According to the passage, food, water, shelter, space, and sunlight are examples of

- **F** populations.
- **G** things found in Yellowstone National Park.
- **H** competition.
- **I** resources.

3. Based on the passage, which of the following statements is a fact?

- **A** Competition occurs only between individuals of different populations.
- **B** Competition occurs between individuals within a population and between individuals of different populations.
- **C** Competition increases the amount of resources available to individuals.
- **D** Because resources are abundant in the environment, competition rarely happens between individuals of different populations.

Passage 2 In the deserts of northern Africa and the Middle East, water is a scarce and valuable resource. In this area, no permanent streams flow except for the Nile. More than 1.6 million square kilometers of this region typically have no rainfall for years at a time. However, much of this area has large aquifers. The water that these aquifers contain dates back to much wetter times thousands of years ago. Occasionally, water reaches the surface to form an oasis. Wells supply the rest of the water used throughout the region. In some regions of Saudi Arabia and Kuwait, wells drilled for water more often strike oil.

1. According to the passage, an aquifer contains what resource?

- **A** oil
- **B** water
- **C** wells
- **D** oasis

2. Based on the passage, which of the following statements is a fact?

- **F** The Nile no longer flows through northern Africa and the Middle East.
- **G** The water found in aquifers is from recent rainfall.
- **H** Wells drilled in Saudi Arabia and Kuwait are more likely to strike oil than water.
- **I** The desert regions of northern Africa and the Middle East receive rainfall almost every day.

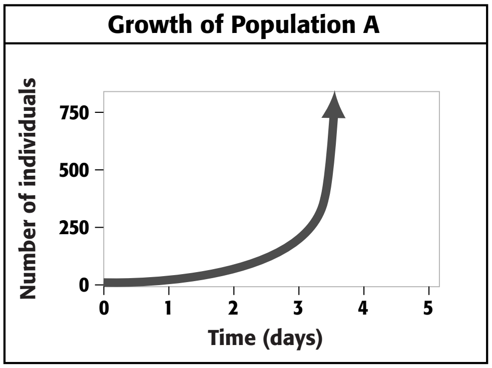
3. According to the passage, an oasis forms under what conditions?

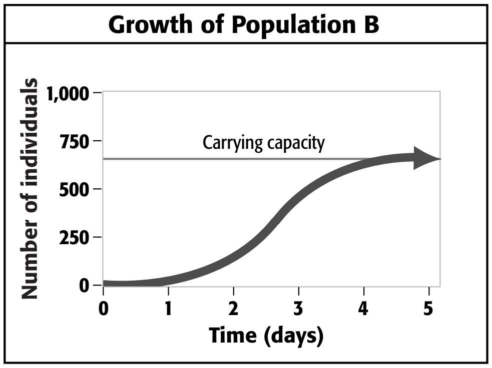
- **A** when water stays beneath the surface
- **B** when water is drilled from a well
- **C** when it rains
- **D** when water reaches the surface

Copyright © by Holt, Rinehart and Winston. All rights reserved.

INTERPRETING GRAPHICS

The graphs below show the population growth for two populations. Use these graphs to answer the questions that follow.





1. After 2 days, which population has more individuals?

A Population A has more individuals.
B Population B has more individuals.
C The populations are the same.
D There is not enough information to determine the answer.

2. After 5 days, which population has more individuals?

F Population A has more individuals.
G Population B has more individuals.
H The populations are the same.
I There is not enough information to determine the answer.

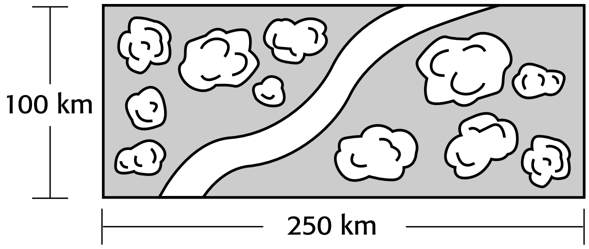
3. On day 10, which statement is probably true?

A Population B is larger than population A.
B Population A is the same as it was on day 5.
C Population A and B are the same.
D Population B is the same as it was on day 5.

MATH

Read each question below, and choose the best answer.

1. The figure below is a map of a forest ecosystem. What is the area of this ecosystem?



A 25,000 km²
B 32,000 km
C 1,200 km²
D 2,500 km

2. If an antelope eats 7 kg of vegetation in 2 days, how many kilograms of vegetation does it eat per day?

F 2/7 kg
G 3/5 kg
H 3 1/2 kg
I 7 1/2 kg

3. If $x = 3$ and $y = x + 2$, what is y?

A 2
B 4
C 5
D 8

4. If $x = 4$ and $y = x + 2$, what is y?

F 2
G 5
H 6
I 8

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Science in Action

Scientific Debate

How Did Dogs Become Pets?

Did humans change dogs to be the social and helpful creatures they are today? Or were dogs naturally social? Did dogs start moving closer to our campfires long ago? Or did humans find dogs and bring them into our homes? The way in which dogs became our friends, companions, and helpers is still a question. Some scientists think humans and training are the reasons for many of our dogs' best features. Other scientists think dogs and humans have both changed over time to form their strong and unique bond.

Math ACTIVITY

Scientists have found fossils of dogs that are 15,000 years old. Generation time is the time between the birth of one generation and the next. If the generation time for dogs is 1.5 years, how many generations have there been in the last 15,000 years?

Weird Science

Follicle Mites

What has a tiny tubelike body and short stumpy legs and lives in your eyebrows and eyelashes? Would you believe a small animal lives there? It's called a follicle mite, and humans are its host. Studies show that more than 97% of adults have these mites. Except in rare cases, follicle mites are harmless.

Like all large animals, human beings are hosts to a variety of smaller creatures that live in or on our bodies and share our bodies' resources. Bacteria that live in our lower digestive tracks help to produce vitamins such as folic acid and vitamin K. Other bacteria may help maintain proper pH levels in our bodies.

Language Arts ACTIVITY

WRITING SKILL Imagine that you were shrunk to the size of a follicle mite. How would you get food? Where would you sleep? Write a short story describing one day in your new, tiny life.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Dalton Dockery

Horticulture Specialist Did you know that instead of using pesticides to get rid of insects that are eating the plants in your garden, you can use other insects? "It is a healthy way of growing vegetables without the use of chemicals and pesticides, and it reduces the harmful effects pesticides have on the environment," says Dalton Dockery, a horticulture specialist in North Carolina. Some insects, such as ladybugs and praying mantises, are natural predators of many insects that are harmful to plants. They will eat other bugs but leave your precious plants in peace. Using bugs to drive off pests is just one aspect of natural gardening. Natural gardening takes advantage of relationships that already exist in nature and uses these interactions to our benefit. For Dockery, the best parts about being a horticultural specialist are teaching people how to preserve the environment, getting to work outside regularly, and having the opportunity to help people on a daily basis.

Social Studies ACTIVITY

WRITING SKILL Research gardening or farming techniques in other cultures. Do other cultures use any of the same aspects of natural gardening as horticultural specialists? Write a short report describing your findings.

go.hrw.com

To learn more about these Science in Action topics, visit **go.hrw.com** and type in the keyword **HL5INTF.**

Current Science

Check out Current Science® articles related to this chapter by visiting go.hrw.com. Just type in the keyword HL5CS18.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

19

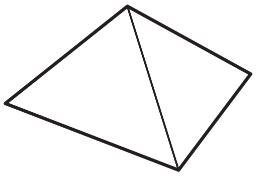
Cycling of Matter

About the PHOTO

These penguins have a unique playground on this iceberg off the coast of Antarctica. Icebergs break off from glaciers and float out to sea. A glacier is a giant "river" of ice that slides slowly downhill. Glaciers are formed from snow piling up in mountains. Eventually, glaciers and icebergs melt and become liquid water. Water in oceans and lakes rises into the air and then falls down again as rain or snow. There is a lot of water on Earth, and most of it is constantly moving and changing form.

PRE-READING ACTIVITY

FOLDNOTES **Pyramid** Before you read the chapter, create the FoldNote entitled "Pyramid" described in the **Study Skills** section of the Appendix. Label the sides of the pyramid with "Water cycle," "Carbon cycle," and "Nitrogen cycle." As you read the chapter, define each cycle, and write the steps of each cycle on the appropriate pyramid side.



Copyright © by Holt, Rinehart and Winston. All rights reserved.

START-UP ACTIVITY

Making Rain

Do you have the power to make rain? Yes!—on a small scale. In this activity, you will cause water to change state in the same way that rain is formed. This process is one way that water is reused on Earth.

Procedure

1. Start with a **large, sealable, plastic freezer bag.** Be sure that the bag is clean and dry and has no leaks. Place a **small, dark-colored bowl** inside the bag. Position the bag with the opening at the top.
2. Fill the bowl halfway with water. Place a few drops of **red food coloring** in the water. Seal the bag.
3. Place the bowl and bag under a strong, warm **light source,** such as a lamp or direct sunlight.
4. Leave the bag in the light for as long as possible. Observe the bag at regular time intervals.

Analysis

1. Each time you observe the bag, describe what you see. Explain what you think is happening.
2. After observing the bag several times, carefully remove the bowl from the bag. Observe and describe any water that is now in the bag. Where did this water come from? How does it differ from the water in the bowl?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 1

The Water, Nitrogen, and Carbon Cycles

READING WARM-UP

Objectives

- Diagram the water cycle, and explain its importance to living things.
- Diagram the carbon cycle, and explain its importance to living things.
- Diagram the nitrogen cycle, and explain its importance to living things.

Terms to Learn

evaporation
condensation
precipitation
decomposition
combustion

READING STRATEGY

Mnemonics As you read this section, create a mnemonic device to help you remember the parts of the water cycle.

The matter in your body has been on Earth since the planet formed billions of years ago!

Matter on Earth is limited, so the matter is used over and over again. Each kind of matter has its own cycle. In these cycles, matter moves between the environment and living things.

The Water Cycle

The movement of water between the oceans, atmosphere, land, and living things is known as the *water cycle*. The parts of the water cycle are shown in **Figure 1.**

How Water Moves

During **evaporation,** the sun's heat causes water to change from liquid to vapor. In the process of **condensation,** the water vapor cools and returns to a liquid state. The water that falls from the atmosphere to the land and oceans is **precipitation.** Rain, snow, sleet, and hail are forms of precipitation. Most precipitation falls into the ocean. Some of the precipitation that falls on land flows into streams, rivers, and lakes and is called *runoff*. Some precipitation seeps into the ground and is stored in spaces between or within rocks. This water, known as *groundwater,* will slowly flow back into the soil, streams, rivers, and oceans.

evaporation the change of a substance from a liquid to a gas

condensation the change of state from a gas to a liquid

precipitation any form of water that falls to the Earth's surface from the clouds

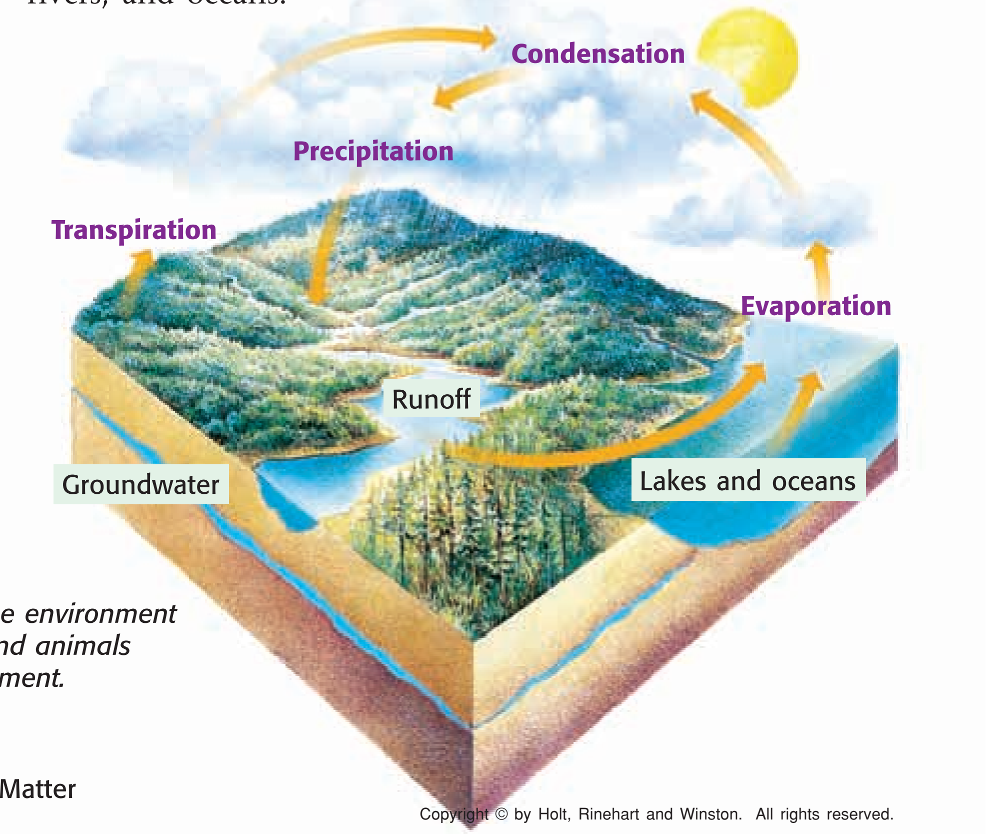


Figure 1 *Water from the environment moves through plants and animals and back to the environment.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

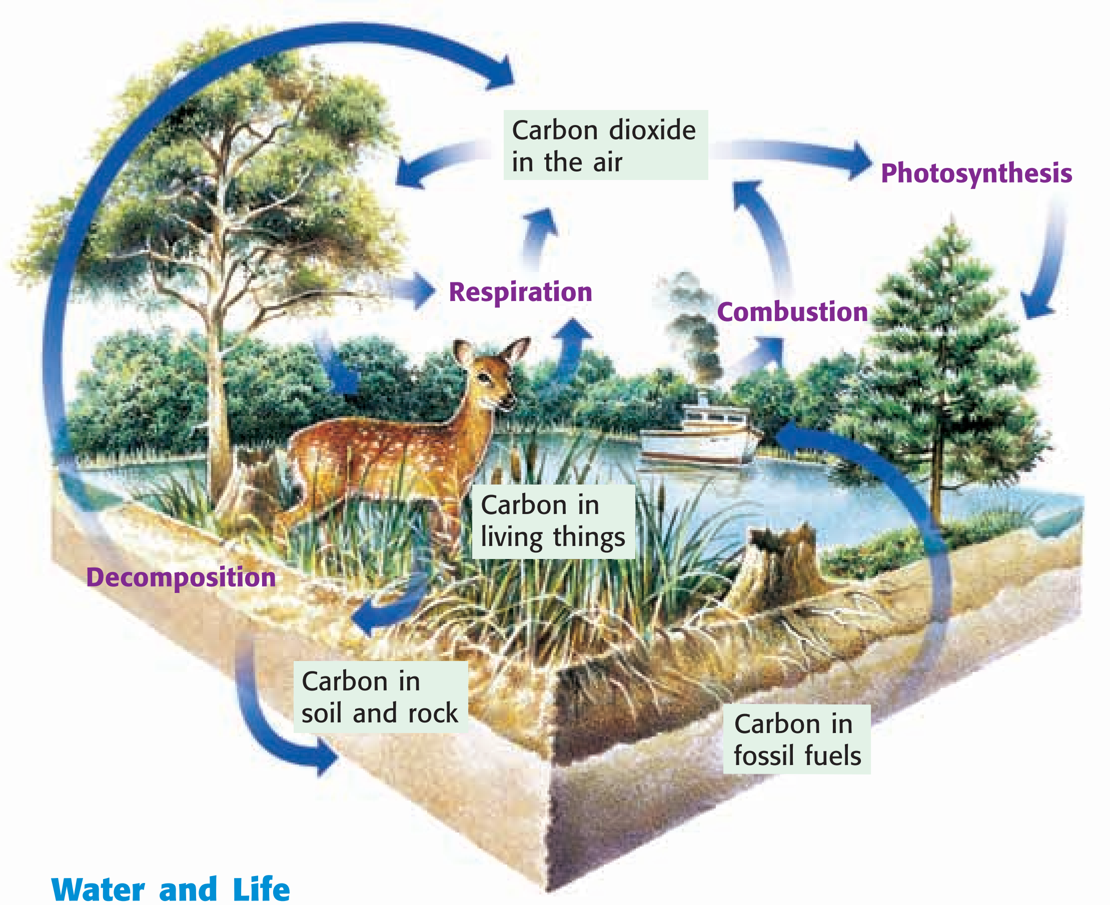


Figure 2 *Carbon may remain in the environment for millions of years before becoming available to living things.*

Water and Life

Without water, there would be no life on Earth. All organisms, from bacteria to animals and plants, are composed mostly of water. Water helps transport nutrients and wastes within an organism. Water also helps regulate temperature. For example, when you sweat, water evaporates from your skin and cools your body. Eventually, all the water taken in by organisms is returned to the environment. For example, plants release a large amount of water vapor in a process called *transpiration*.

Reading Check **Why is water important?** (*See the Appendix for answers to Reading Checks.*)

MATH PRACTICE

Where's the Water?

There are about 37.5 million cubic kilometers of fresh water on Earth. Of this fresh water, about 8.3 million cubic kilometers is groundwater. What percentage of Earth's fresh water is groundwater?

The Carbon Cycle

Besides water, the most common molecules in living things are *organic* molecules, or molecules that contain carbon. The exchange of carbon between the environment and living things is known as the *carbon cycle*, as shown in **Figure 2.**

Photosynthesis and Respiration

Photosynthesis is the basis of the carbon cycle. During photosynthesis, plants use carbon dioxide from air to make sugars. Most animals get the carbon and energy they need by eating plants. How does carbon return to the environment? It returns when sugar molecules are broken down to release energy. This process, called *respiration*, uses oxygen. Carbon dioxide and water are released as byproducts of respiration.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

decomposition the breakdown of substances into simpler molecular substances

combustion the burning of a substance

QuickLab

Combustion

1. Place a **candle** on a **jar lid,** and secure the candle with **modeling clay.** Have your teacher light the candle.
2. Hold the jar near the candle flame. Do not cover the flame with the jar. Describe the jar. Where did the substance on the jar come from?
3. Now, place the jar over the candle. What is deposited inside the jar? Where did this substance come from?

Decomposition and Combustion

The breakdown of substances into simpler molecules is called **decomposition.** For example, when fungi and bacteria decompose organic matter, carbon dioxide and water are returned to the environment. You may have witnessed another way to break down organic matter—using fire. **Combustion** is the process of burning a substance, such as wood or fossil fuels. Like decomposition, combustion of organic matter releases carbon dioxide into the atmosphere.

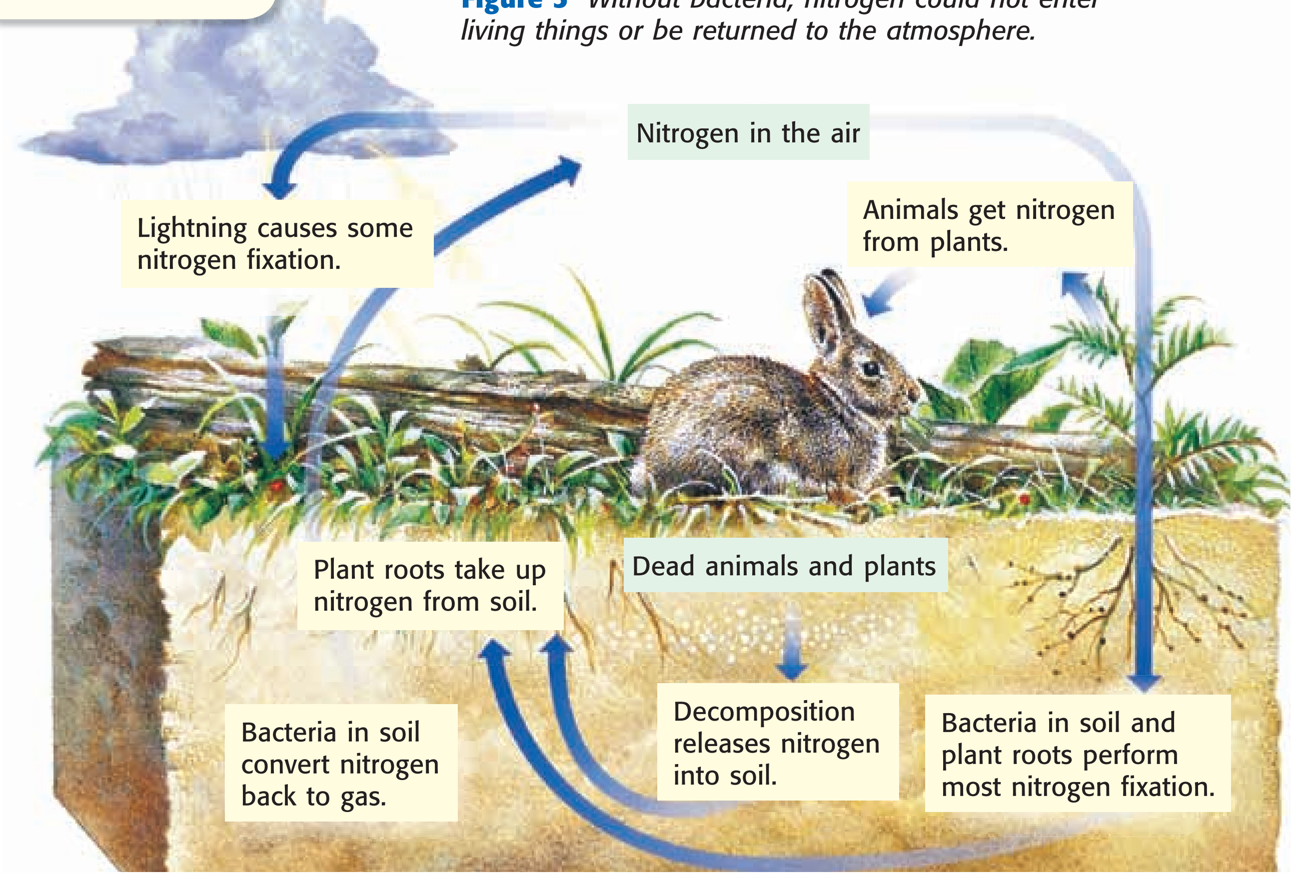
The Nitrogen Cycle

Nitrogen is also important to living things. Organisms need nitrogen to build proteins and DNA for new cells. The movement of nitrogen between the environment and living things is called the *nitrogen cycle.* This cycle is shown in **Figure 3.**

Converting Nitrogen Gas

About 78% of the Earth's atmosphere is nitrogen gas. Most organisms cannot use nitrogen gas directly. However, bacteria in the soil are able to change nitrogen gas into forms that plants can use. This process is called *nitrogen fixation.* Other organisms may then get the nitrogen they need by eating plants or eating organisms that eat plants.

Figure 3 *Without bacteria, nitrogen could not enter living things or be returned to the atmosphere.*



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Passing It On

When organisms die, decomposers break down the remains. Decomposition releases a form of nitrogen into the soil that plants can use. Finally, certain types of bacteria in the soil convert nitrogen to a gas, which is returned to the atmosphere.

Many Cycles

Other kinds of matter on Earth also pass through cycles. Many of the minerals that living cells need, such as calcium and phosphorus, are cycled through the environment. Oxygen is also cycled through the environment. For example, oxygen is part of the carbon dioxide and water molecules taken in by plants for photosynthesis. The oxygen is used to make sugars, or it is released back into the atmosphere as oxygen gas.

Each of the cycles is connected in many ways. For example, some forms of nitrogen and carbon are carried through the environment by water. Many nutrients pass from soil to plants to animals and back. Living organisms play a part in each of the cycles. When an organism dies, every substance in its body is likely to be recycled or reused.

CONNECTION TO Environmental Science

Global Warming The quantity of carbon dioxide being released into the atmosphere is increasing. Carbon dioxide can cause the atmosphere to hold heat. A warmer atmosphere would cause the temperatures of the land and ocean to increase. Scientists think that this situation, known as *global warming,* may be happening. Research data on changes in average global temperature and carbon dioxide levels for the past 50 years, and summarize your findings.

SECTION Review

Summary

- Precipitation, evaporation, transpiration, and condensation are parts of the water cycle.
- Photosynthesis, respiration, decomposition, and combustion are parts of the carbon cycle.
- In the nitrogen cycle, nitrogen gas is converted into other forms and back to gas again.
- Many forms of matter on Earth pass through cycles. These cycles may be connected in many ways.

Using Key Terms

For each pair of terms, explain how the meanings of the terms differ.

1. *evaporation* and *condensation*
2. *decomposition* and *combustion*

Understanding Key Ideas

3. Nitrogen fixation
   a. is done only by plants.
   b. is done mostly by bacteria.
   c. is how animals make proteins.
   d. is a form of decomposition.
4. Describe the water cycle.
5. Describe the carbon cycle.

Math Skills

6. The average person in the United States uses about 78 gal of water each day. How many liters of water does this equal? How many liters of water will the average person use in a year?

Critical Thinking

7. **Analyzing Processes** Draw a simple diagram of each of the cycles discussed in this section. Draw lines between the cycles to show how parts of each cycle are related.
8. **Applying Concepts** Give an example of how the calcium in an animal's bones might be cycled back into the environment.

SCILINKS. NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Cycles of Matter
SciLinks code: HSM0373

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 2

Ecological Succession

Imagine you have a time machine that can take you back to the summer of 1988. If you had visited Yellowstone National Park during that year, you would have seen fires raging throughout the area.

By the end of that summer, large areas of the park were burned to the ground. When the fires were put out, a layer of gray ash blanketed the forest floor. Most of the trees were dead, although many of them were still standing.

READING WARM-UP

Objectives

- Describe the process of succession.
- Contrast primary and secondary succession.
- Explain how mature communities develop.

Terms to Learn

succession
pioneer species

READING STRATEGY

Reading Organizer As you read this section, make a table comparing primary succession and secondary succession.

Regrowth of a Forest

The following spring, the appearance of the "dead" forest began to change. **Figure 1** shows the changes after just one year. Some of the dead trees fell over, and small, green plants grew in large numbers. Within 10 years, scientists reported that many trees were growing and the forest community was coming back.

A gradual development of a community over time, such as the regrowth of the burned areas of Yellowstone National Park, is called **succession.** Succession takes place in all communities, not just those affected by disturbances such as forest fires.

succession the replacement of one type of community by another at a single place over a period of time

Reading Check What happened after the Yellowstone fires? (*See the Appendix for answers to Reading Checks.*)

Figure 1 *Huge areas of Yellowstone National Park were burned in 1988* (left). *By the spring of 1989, regrowth was evident in the burned parts of the park* (right).

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Primary Succession

Sometimes, a small community starts to grow in an area where other organisms had not previously lived. There is no soil in this area. And usually, there is just bare rock. Over a very long time, a series of organisms live and die on the rock. The rock is slowly transformed into soil. This process is called *primary succession,* as shown in **Figure 2.** The first organisms to live in an area are called **pioneer species.**

pioneer species a species that colonizes an uninhabited area and that starts a process of succession

Figure 2 **An Example of Primary Succession**

1 A slowly retreating glacier exposes bare rock where nothing lives, and primary succession begins.

2 Most primary succession begins with lichens. Acids from the lichens begin breaking the rocks into small particles. These particles mix with the remains of dead lichens to start forming soil. Lichens are an example of a pioneer species.

3 After many years, there is enough soil for mosses to grow. The mosses eventually replace the lichens. Insects and other tiny organisms begin to live there. When they die, their remains add to the soil.

4 Over time, the soil deepens, and the mosses are replaced by ferns. The ferns may slowly be replaced by grasses and wildflowers. If there is enough soil, shrubs and small trees may grow.

5 After hundreds or even thousands of years, the soil may be deep and stable enough to support a forest.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

INTERNET ACTIVITY

For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HL5CYCW.**

Secondary Succession

Sometimes, an existing community is destroyed by a natural disaster, such as a fire or a flood. Sometimes, a community is affected by another type of disturbance. For example, a farmer might stop growing crops in an area that had been cleared. In either case, if soil is left intact, the original community may regrow through a series of stages called *secondary succession*. **Figure 3** shows an example of secondary succession.

Reading Check **How does secondary succession differ from primary succession?**

Figure 3 **An Example of Secondary Succession**

1 The first year after a farmer stops growing crops or the first year after some other major disturbance, weeds start to grow. In farming areas, crab grass is the weed that often grows first.

2 By the second year, new weeds appear. Their seeds may have been blown into the field by the wind, or insects may have carried them. Horseweed is common during the second year.

3 In 5 to 15 years, small conifer trees may start growing among the weeds. The trees continue to grow, and after about 100 years, a forest may form.

4 As older conifers die, they may be replaced by hardwoods, such as oak or maple trees, if the climate can support them.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Mature Communities and Biodiversity

In the early stages of succession, only a few species grow in an area. These species grow quickly and make many seeds that scatter easily. But all species are vulnerable to disease, disturbances, and competition. As a community matures, it may be dominated by well-adapted, slow-growing *climax species*.

Furthermore, as succession proceeds, more species may become established. The variety of species that are present in an area is referred to as *biodiversity*. Biodiversity is important to communities of organisms. For example, a forest that has a high degree of biodiversity is less likely to be destroyed by an invasion of insects. Most plant-damaging insects prefer to attack only one species of plants. The presence of a variety of plants will lessen the impact and spread of invading insects.

Keep in mind that a mature community may not always be a forest. A mature community simply has organisms that are well adapted to live together in the same area over time. For example, the plants of the Sonoran Desert, shown in **Figure 4,** are well-adapted to the desert's conditions.

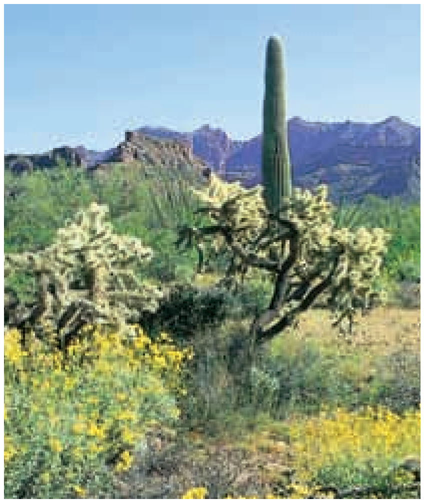


Figure 4 *This area of the Sonoran Desert in Arizona is a mature community.*

SECTION Review

Summary

- Ecological succession is the gradual development of communities over time. Often a series of stages is observed during succession.
- Primary succession occurs in an area that was not previously inhabited by living things; no soil is present.
- Secondary succession takes place in an area where an earlier community was disturbed by fire, landslides, floods, or plowing for crops and where soil is present.

Using Key Terms

1. In your own words, write a definition for the term *succession*.

Understanding Key Ideas

2. An area where a glacier has just melted away will begin the process of
   a. primary succession.
   b. secondary succession.
   c. stability.
   d. regrowth.
3. Describe succession that takes place in an abandoned field.
4. Describe a mature community. How does a mature community develop?

Math Skills

5. The fires in 1988 burned 739,000 of the 2.2 million acres that make up Yellowstone National Park. What percentage of the park was burned?

Critical Thinking

6. **Applying Concepts** Give an example of a community that has a high degree of biodiversity, and an example of one that has a low degree of biodiversity.
7. **Analyzing Ideas** Explain why soil formation is always the first stage of primary succession. Does soil formation ever stop? Explain your answer.

SCILINKS® NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Succession
SciLinks code: HSM1475

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 3

Photosynthesis

Like you, plants need air. Air contains oxygen, carbon dioxide, and other gases. You need oxygen, and plants need oxygen. But what other gas is important to plants?

READING WARM-UP

Objectives

- Describe photosynthesis.
- Compare photosynthesis and cellular respiration.
- Describe how gas is exchanged in the leaves of plants.
- Describe two ways in which photosynthesis is important.

Terms to Learn

photosynthesis
chlorophyll
cellular respiration
stoma
transpiration

READING STRATEGY

Discussion Read this section silently. Write down questions that you have about this section. Discuss your questions in a small group.

If you guessed *carbon dioxide,* you are correct! Plants use carbon dioxide for photosynthesis (FOHT oh SIN thuh sis). **Photosynthesis** is the process by which plants, algae, and some bacteria make their own food. These organisms capture energy from sunlight during photosynthesis. This energy is used to make the sugar glucose from carbon dioxide and water.

Capturing Light Energy

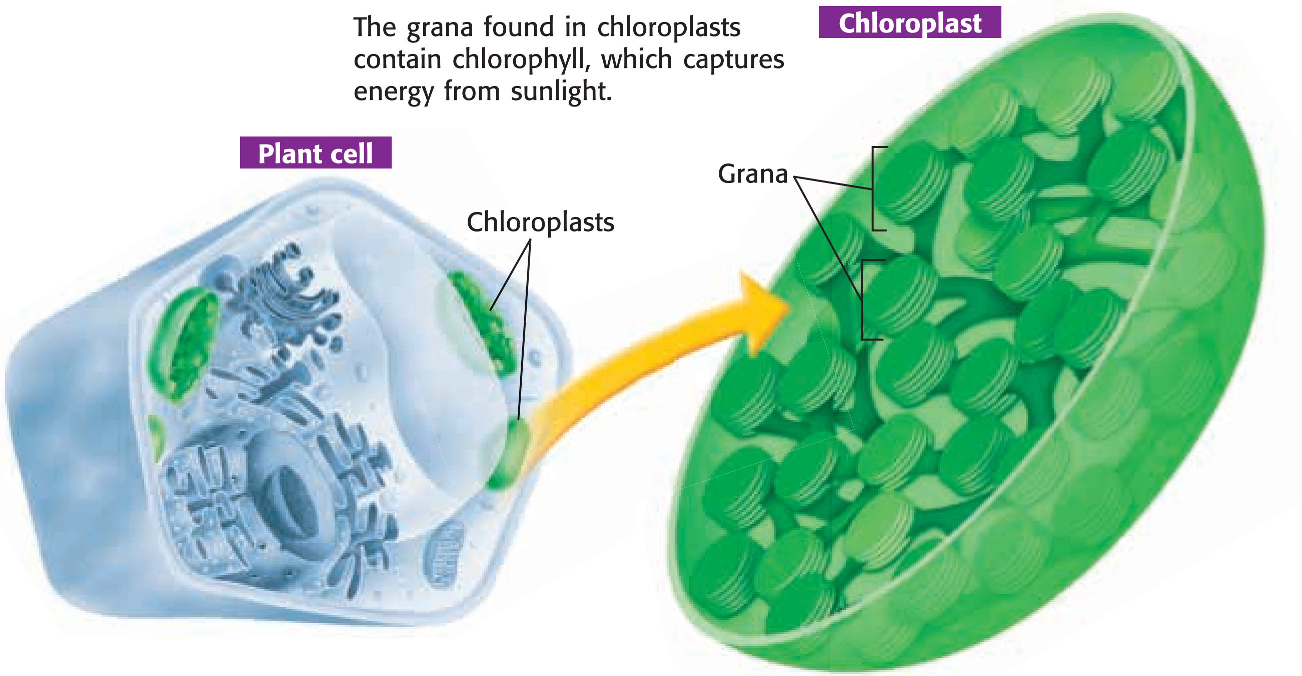
Plant cells have organelles called *chloroplasts* (KLAWR uh PLASTS), shown in **Figure 1.** A chloroplast is surrounded by two membranes. Inside the chloroplast, another membrane forms stacks called *grana* (GRAY nuh). Grana contain a green pigment, called **chlorophyll** (KLAWR uh FIL), that absorbs light energy. Chlorophyll is also found in algae and photosynthetic bacteria.

Sunlight is made up of many different wavelengths of light. Chlorophyll absorbs many of these wavelengths. But it reflects more wavelengths of green light than wavelengths of other colors of light. So, most plants look green.

Reading Check **Why are most plants green?** (*See the Appendix for answers to Reading Checks.*)

Figure 1 Chloroplast Structure

The grana found in chloroplasts contain chlorophyll, which captures energy from sunlight.



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Making Sugar

The light energy captured by chlorophyll is used to help form glucose molecules. In turn, oxygen gas is given off by plant cells. Photosynthesis is a complicated process made up of many steps. But photosynthesis can be summarized by the following chemical equation:

$$6CO_2 + 6H_2O \xrightarrow{\textit{light energy}} C_6H_{12}0_6 + 6O_2$$

Six molecules of carbon dioxide, CO_2, and six molecules of water, H_2O, are needed to form one molecule of glucose, $C_6H_{12}O_6$, and six molecules of oxygen gas, O_2. **Figure 2** shows where plants get the materials for photosynthesis.

photosynthesis the process by which plants, algae, and some bacteria use sunlight, carbon dioxide, and water to make food

chlorophyll a green pigment that captures light energy for photosynthesis

Getting Energy from Sugar

Glucose molecules store energy. Plant cells use this energy for their life processes. To get energy, plant cells break down glucose and other food molecules in a process called **cellular respiration.** During this process, plant cells use oxygen. The cells give off carbon dioxide and water. Excess glucose is converted to another sugar called *sucrose* or stored as starch.

cellular respiration the process by which cells use oxygen to produce energy from food

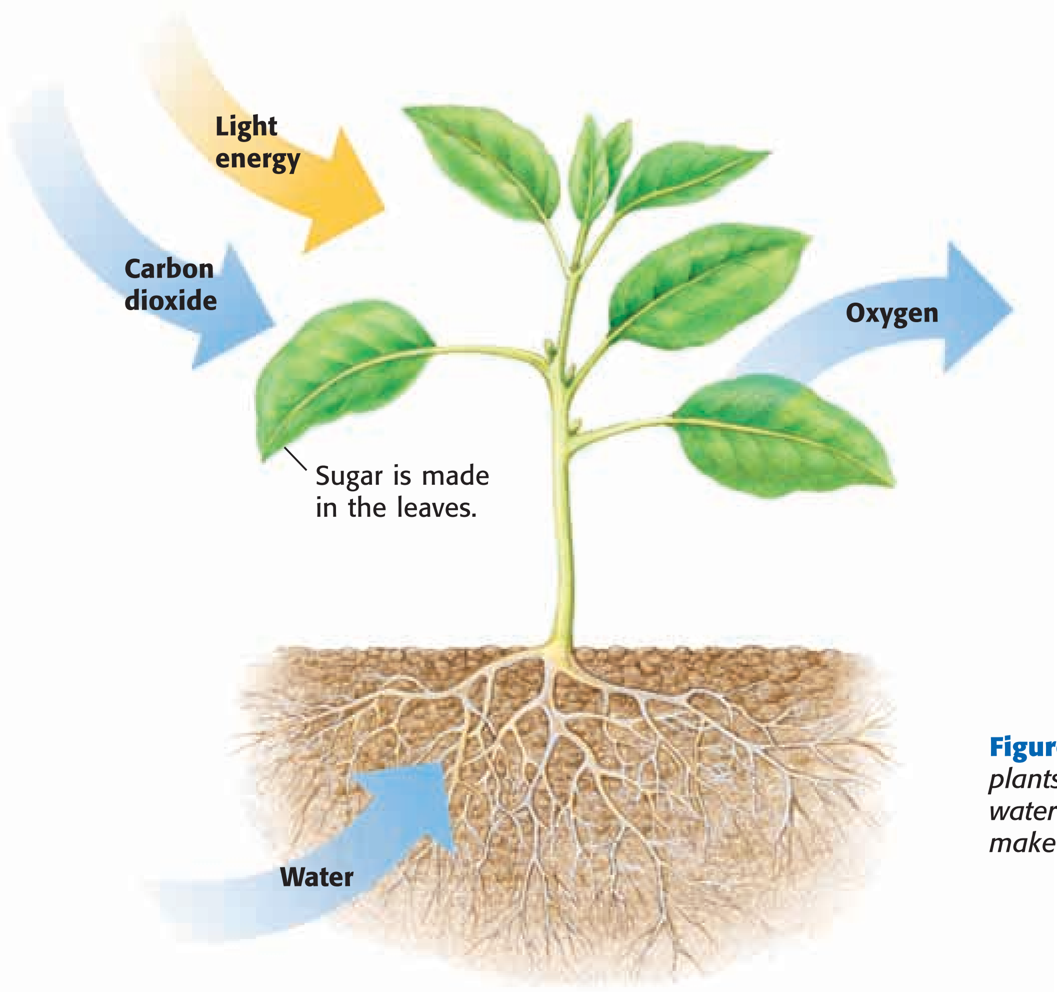
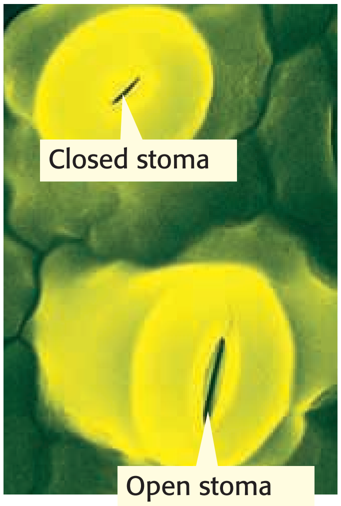


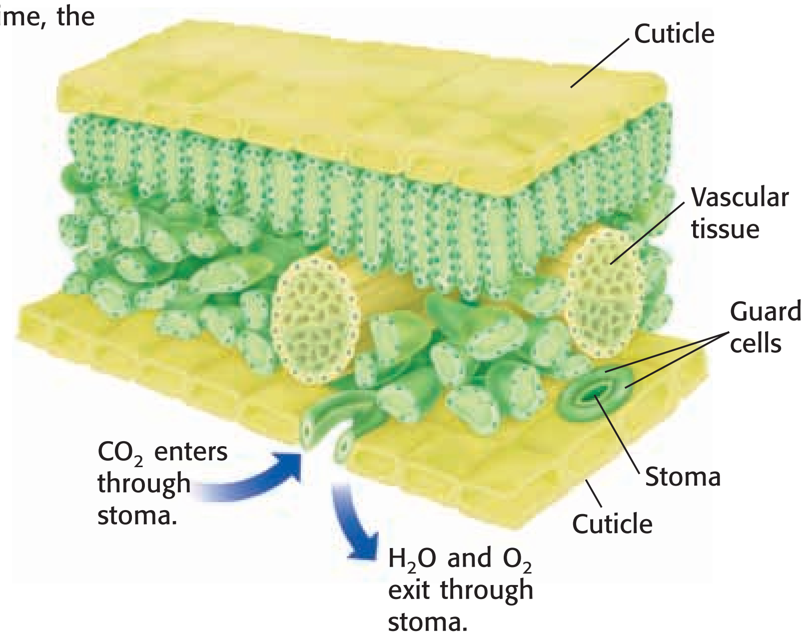
Figure 2 *During photosynthesis, plants take in carbon dioxide and water and absorb light energy. They make sugar and release oxygen.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 3 **Gas Exchange in Leaves**

When light is available for photosynthesis, the stomata are usually open. At nighttime, the stomata close to conserve water.





Gas Exchange

Many above-ground plant surfaces are covered by a waxy cuticle. The cuticle protects the plant from water loss. How does a plant get carbon dioxide through this barrier? Carbon dioxide enters the plant's leaves through stomata (singular, *stoma*). A **stoma** is an opening in the leaf's epidermis and cuticle. Each stoma is surrounded by two *guard cells*. The guard cells act like double doors, opening and closing the stoma. You can see stomata in **Figure 3.**

When stomata are open, carbon dioxide enters the leaf. The oxygen produced during photosynthesis exits the leaf through the stomata. Water vapor also exits the leaf in this way. The loss of water from leaves is called **transpiration.** Most of the water absorbed by a plant's roots replaces the water lost during transpiration. Sometimes, more water is lost through a plant's leaves than is absorbed by the plant's roots. When this happens, the plant wilts.

stoma one of many openings in a leaf or a stem of a plant that enable gas exchange to occur (plural, *stomata*)

transpiration the process by which plants release water vapor into the air through stomata

CONNECTION TO Chemistry

Transpiration Wrap a plastic bag around the branch of a tree or a portion of a potted plant. Secure the bag closed with a piece of tape or a rubber band, but be sure not to injure the plant. Record what happens over the next few days. What happened to the bag? How does this illustrate transpiration?

ACTIVITY

Copyright © by Holt, Rinehart and Winston. All rights reserved.

The Importance of Photosynthesis

Plants and other photosynthetic organisms, such as some bacteria and many protists, form the base of nearly all food chains on Earth. An example of one food chain is shown in **Figure 4.**

During photosynthesis, plants store light energy as chemical energy. Some animals use this chemical energy when they eat plants. Other animals get energy from plants indirectly. These animals eat animals that eat plants. Most organisms could not survive without photosynthetic organisms.

Oxygen is a byproduct of photosynthesis. Photosynthetic organisms produce almost all of the oxygen found in the atmosphere. Plants, animals, and most other organisms use this oxygen for cellular respiration.

Reading Check What are two ways in which photosynthesis is important?

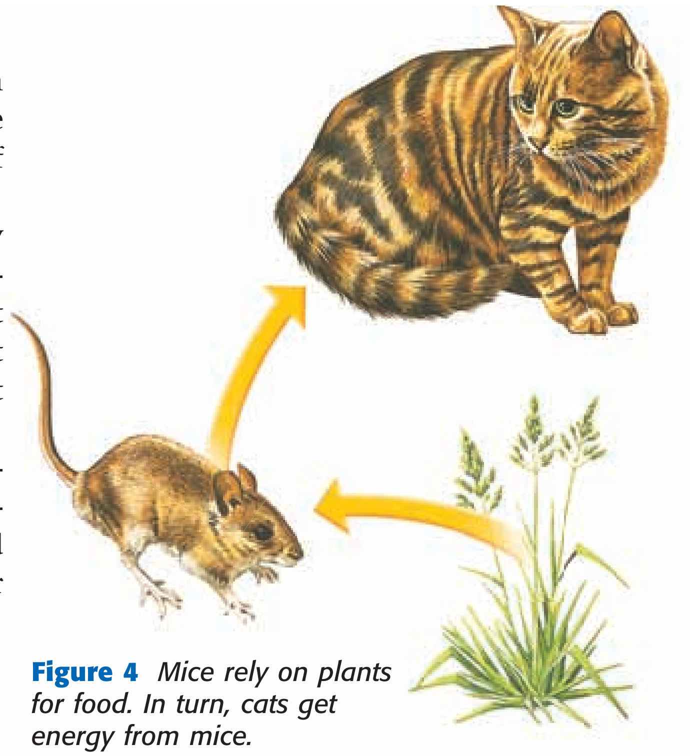


Figure 4 *Mice rely on plants for food. In turn, cats get energy from mice.*

SECTION Review

Summary

- During photosynthesis, plants use energy from sunlight, carbon dioxide, and water to make food.
- Plants get energy from food by cellular respiration, which uses oxygen and releases carbon dioxide and water.
- Transpiration, or the loss of water through the leaves, happens when stomata are open.
- Photosynthesis provides oxygen. Most animals rely on photosynthetic organisms for food.

Using Key Terms

1. In your own words, write a definition for each of the following terms: *photosynthesis*, *chlorophyll*, and *cellular respiration*.

Understanding Key Ideas

2. Photosynthetic organisms
   a. provide oxygen for cellular respiration.
   b. form the base of nearly all food chains on Earth.
   c. store light energy as chemical energy.
   d. All of the above
3. Describe gas exchange in plants.

Math Skills

4. Plants use 6 carbon dioxide molecules and 6 water molecules to make 1 glucose molecule. How many carbon dioxide and water molecules would be needed to make 12 glucose molecules?

Critical Thinking

5. **Predicting Consequences** Predict what might happen if plants and other photosynthetic organisms disappeared.
6. **Applying Concepts** Light filters let through certain colors of light. Predict what would happen if you grew a plant under a green light filter.

SCILINKS® NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Photosynthesis
SciLinks code: HSM1140

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 4

Responding to the Environment

What do you need to get through the day? Maybe you answered "food." But did you include water, light, and other abiotic factors in your answer?

READING WARM-UP

Objectives

- List five abiotic factors that affect the growth and survival of organisms.
- Identify the role of water in the survival of organisms.
- Describe an example of a limiting factor.

Terms to Learn

limiting factor

READING STRATEGY

Reading Organizer As you read this section, create an outline of the section. Use the headings from the section in your outline.

Abiotic factors are the nonliving parts of the environment. Abiotic factors include light, temperature, minerals, soil, rocks, and water. *Biotic factors* are the living parts and the once-living parts of the environment. Biotic factors include living and dead organisms. Without several important abiotic factors, organisms, including humans, could not survive.

Necessities for Life

Like any other living organism, you need food to live. But organisms also need several abiotic factors to live. These abiotic factors include water, light, favorable temperatures, nutrients, and soil. For example, the trees in **Figure 1** could not make their own food without the light and water in their environment.

Populations cannot grow forever. The environment contains a limited amount of food and abiotic factors. Sometimes, a single resource is so scarce that it limits the size of a population. This resource, called a **limiting factor,** keeps the population from reaching its full potential. For example, during a drought, an area receives less rainfall than it usually does. As a result, fewer organisms can survive in the area.

limiting factor an environmental factor that prevents an organism or population from reaching its full potential of distribution or activity

Reading Check **What are five abiotic factors that living organisms need?** (*See the Appendix for answers to Reading Checks.*)

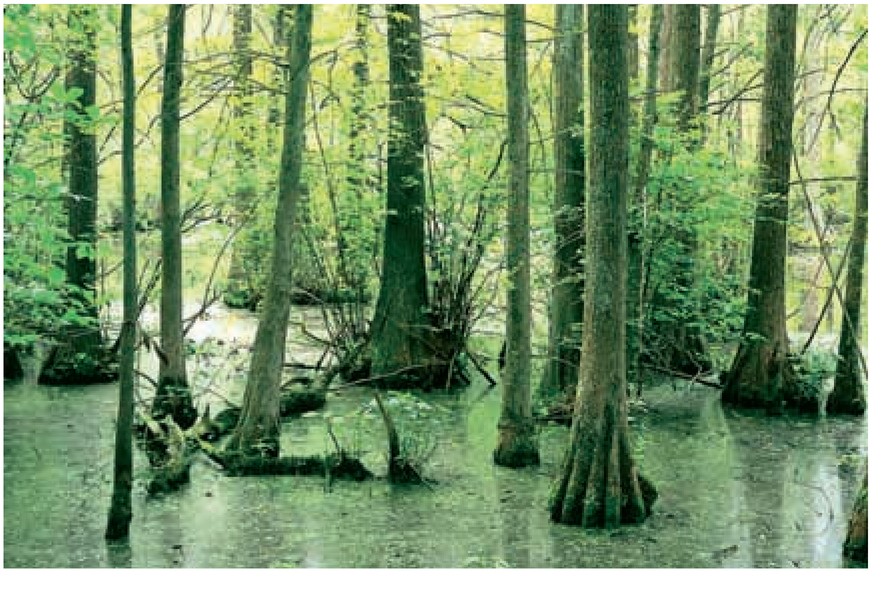


Figure 1 *The trees in this swamp rely on abiotic factors, such as water and light, to survive.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Water

For most living organisms, water makes up the largest part of their body. In fact, about 70% of the human body is made up of water. Many organisms cannot survive for more than a few days without water. Organisms need water for many life processes. Without water, life on Earth would not exist.

Animals

Animals rely on water both directly and indirectly. Animals need water so that their cells and bodies function properly. Many animals, such as the frog in **Figure 2,** live in or near water. Fishes, amphibians, and some reptiles and mammals make their homes in marine or freshwater environments. Other animals may consume animals that live in marine and freshwater environments.

Some animals have unique adaptations that help them survive when there is a lack of water. For example, some desert animals, such as the spadefoot toad, bury themselves in the ground and are dormant during the dry season. Other animals, such as camels, can store large amounts of water in their blood. This stored water helps camels survive long dry periods.

Figure 2 *Many amphibians, such as this frog, need a very wet environment to survive.*

Plants

Plants need water for life processes, such as photosynthesis. During photosynthesis, plants make glucose out of water and carbon dioxide. This glucose is used for energy or is stored as starch. Without water, a plant could not make food.

Water also helps keep plants upright and plays a role in transporting nutrients. When not enough water is available, plants wilt, as shown in **Figure 3,** and may die. Also, plants cannot move some nutrients from one part of the plant to another part without water.

Figure 3 *These flowering plants wilted because they were not getting enough water.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Light

Light is another important abiotic factor in the environment. Light provides energy and warmth.

Photosynthesis and Plants

During photosynthesis, light energy is converted into chemical energy in the form of sugars and starches. When an organism eats a plant or eats another organism that ate plants, the organism receives some of this energy. Photosynthetic organisms, such as plants, algae, and some bacteria, form the base of nearly every food chain on Earth.

Light also affects plants in other ways. For example, day length can determine when some species of flowering plants, such as the poinsettias in **Figure 4,** bloom. Some plants bloom when days are long. Other plants, including poinsettias, bloom when days are short.

Animals

Animals depend on light for the growth of the plants that the animals eat. Light also enables many animal species to see during the day. Without light, these animals would have a hard time hunting, staying away from predators, or finding food. In much the same way that light affects the blooming of plants, light can affect when some animals reproduce. Many species of birds and fishes do not mate until the days reach a certain length. Day length also affects the migration of some animals, such as Monarch butterflies and many bird species.

Reading Check **How do animals rely on light?**

CONNECTION TO Social Studies

WRITING SKILL **Designed Natural Areas**

People design and build systems, such as botanical gardens and zoos, to preserve plants and animals. Identify one plant and one animal found in botanical gardens and zoos. In your **science journal,** evaluate how these systems help the organisms that you chose grow, and describe any limitations of the systems.

Figure 4 *Gardeners control the blooming of poinsettias by controlling the amount of light that the plants receive.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

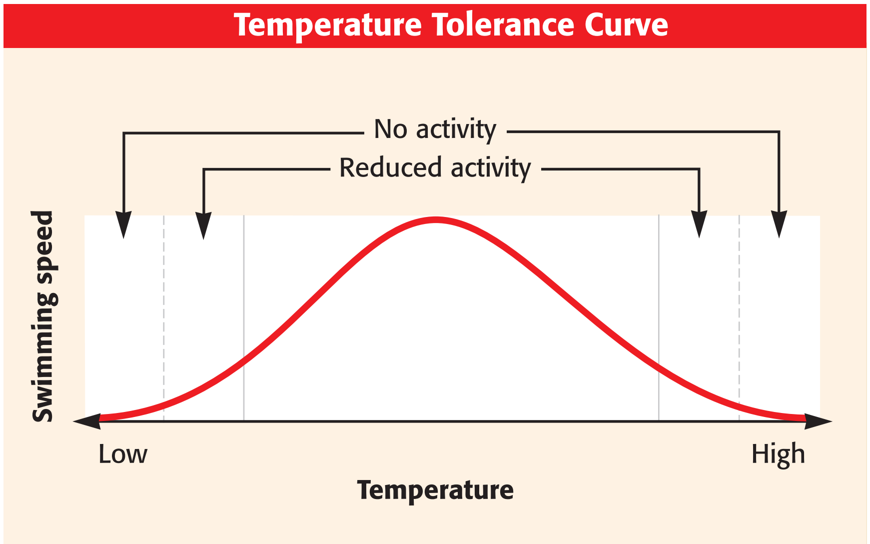


Figure 5 *Many fishes have difficulty swimming if the water is too hot or too cold.*

Temperature

Have you ever been outside on an extremely cold day? Your first reaction may have been to go back inside, where it was warm. Organisms need favorable temperatures in order to survive. If temperatures are too cold, an organism may freeze to death. If temperatures are too warm, an organism may overheat.

Many organisms have an ideal range of temperatures in which they can survive. An example of how a fish deals with temperature is shown in **Figure 5.** In temperatures outside of the fish's ideal temperature range, the fish slows down. The feeding ability of many animals, such as barnacles, is also affected by temperature. At certain temperatures, barnacles are unable to eat.

Temperature also affects the reproduction of organisms. Some flowering plants do not bloom unless they have first been exposed to freezing temperatures. Many animals, such as whales, migrate to warmer areas before reproducing.

Figure 6 *The amount of nitrogen or phosphorus in water limits the growth of diatoms.*

Nutrients

A nutrient is a substance that provides energy or helps the body build and repair itself. You get nutrients, such as carbohydrates, proteins, and fats, from the foods that you eat. Minerals, vitamins, and water are also nutrients. Organisms, such as the diatoms in **Figure 6,** need nutrients in various amounts to meet their needs. As you may know, many mineral nutrients are cycled through the environment. Two important minerals are nitrogen and phosphorus. Organisms need nitrogen for DNA and protein molecules. Organisms need phosphorous for cell membranes, DNA, and energy-storage molecules.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

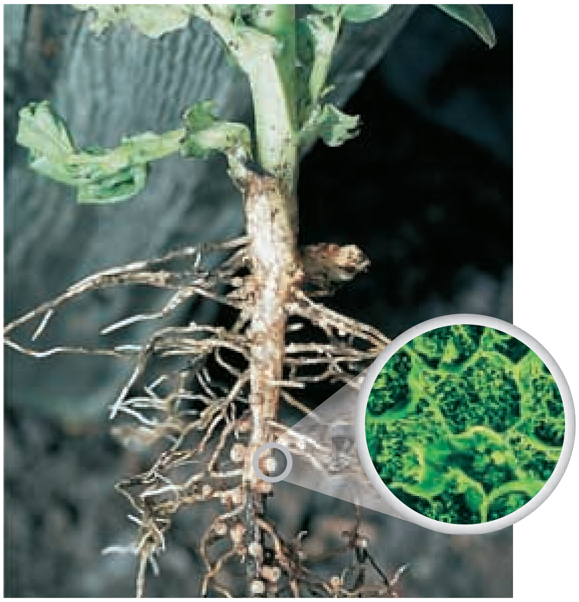


Figure 7 *Nitrogen-fixing bacteria live in nodules on the roots of plants called* legumes, *which include beans and peas.*

Water Habitats

What is an important limiting factor for photosynthetic plankton in marine environments? Some people might guess the amount of light. But often, nitrogen and phosphorous limit the growth of plankton. For example, marine areas that are sunny and warm may not have a great deal of plankton growth. The reason is that little nitrogen or phosphorous is available. Nitrogen and phosphorous also limit the growth of photosynthetic organisms in freshwater environments.

Land Habitats

All organisms need nitrogen to build proteins. Nitrogen makes up about 78% of air. But most organisms cannot use this nitrogen gas. The nitrogen gas must be altered, or fixed, before organisms can use it. Only some species of bacteria can fix nitrogen gas. These bacteria are called *nitrogen-fixing bacteria*. Through a process called *nitrogen fixation*, these bacteria take nitrogen from the air and change it into a form that other organisms can use. The bacteria release some of this usable nitrogen into the soil, from which plants take up the nitrogen. As **Figure 7** shows, some nitrogen-fixing bacteria live in nodules on the roots of some species of plants.

The Role of Decomposers

Decomposers are the environment's recyclers. Decomposers break down dead organisms and wastes, which returns nitrogen to the soil. Without decomposers, nitrogen would not be returned to the environment. The nitrogen would remain stored in dead organisms, where it cannot be used by other organisms.

Quick Lab

The Effect of Fertilizer

1. Label a **1 L jar** "Control," and label a second **1 L jar** "Fertilizer."
2. Add **750 mL of distilled water** and **100 mL of pond water** to each jar. To the jar labeled "Fertilizer," add the recommended amount of **fertilizer** for 750 mL of water.
3. Use a **microscope** to observe a drop of water from each jar. Draw pictures of the organisms that you see.
4. Every other day for the next two weeks, observe a drop of water from each jar and draw what you see.
5. Did the types of organisms in each jar change over time? If so, how did they change?
6. Fertilizer contains nitrogen. Based on your observations, how might fertilizer affect the environment?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Soil

Soil is a mixture of rock particles and decaying matter. Plants rely on soil as a medium in which to grow. Plants obtain nutrients and water from soil. The nutrients and consistency of soil determine the number and types of plants that grow in an area. Some soils hold more mineral nutrients and water, which are necessary for plant growth.

Sometimes, soil becomes depleted of nutrients or water. When this happens, plants do not grow well. In dry areas, soils may become more desertlike. This process is called *desertification*. The loss of soil due to erosion also reduces plant growth.

Reading Check **How is soil important to plant growth?**

SECTION Review

Summary

- Five abiotic factors that determine the growth and survival of living organisms are water, light, favorable temperatures, nutrients, and soil.
- A limiting factor is an environmental factor that keeps a population from reaching its full potential.
- Without water, life on Earth would not exist. Water is needed for photosynthesis and many other life processes.
- Light is needed for photosynthesis and affects the reproduction of many organisms.
- Nitrogen and phosphorus are two important mineral nutrients.

Using Key Terms

1. In your own words, write a definition for the term *limiting factor*.

Understanding Key Ideas

2. Which of the following is an abiotic factor that affects living organisms?
   a. decaying organisms
   b. temperature
   c. plankton
   d. photosynthesis
3. Without decomposers, organisms
   a. could not get water.
   b. would need more light.
   c. would not be able to get some nutrients.
   d. would not be affected.
4. How is water important to the survival of organisms?

Math Skills

5. The ocean covers about 71% of Earth's surface. If the total surface area of Earth is about 510 million square kilometers, how many square kilometers are covered by the ocean?

Critical Thinking

6. **Applying Concepts** What is likely to be a limiting factor in the desert? in the Arctic?
7. **Identifying Relationships** A farmer has been using the same field for several years. Lately, his crops have been doing poorly. Based on what you know about limiting factors, what might explain this poor crop growth? How might the farmer resolve the problem?
8. **Making Inferences** Excess phosphorus in water environments can lead to the increased growth of bacteria. These bacteria may use up oxygen in the water. How might this loss of oxygen affect other organisms in the water?

SciLinks — NSTA — Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Necessities of Life
SciLinks code: HSM1018

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Skills Practice Lab

OBJECTIVES

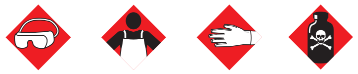
Investigate the nitrogen cycle inside a closed system.

Discover how decomposers return nitrogen to the soil.

MATERIALS

- balance or scale
- beaker, 50 mL
- funnel
- gloves, protective
- graduated cylinder, 25 mL
- insects from home or schoolyard, large, dead (5)
- jar with lid, 1 pt (or 500 mL)
- paper, filter (2 pieces)
- pH paper
- soil, potting, commercially prepared without fertilizer
- water, distilled, 60 mL

SAFETY



Nitrogen Needs

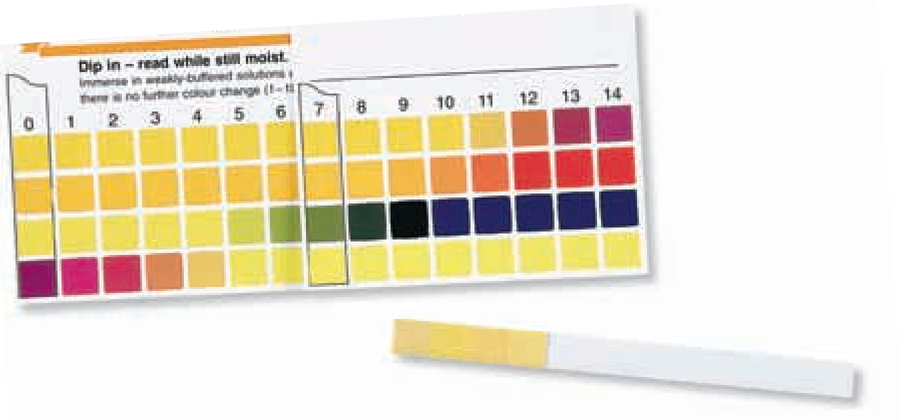
The nitrogen cycle is one of several cycles that are vital to living organisms. Without nitrogen, living organisms cannot make amino acids, the building blocks of proteins. Animals obtain nitrogen by eating plants that contain nitrogen and by eating animals that eat those plants. When animals die, decomposers return the nitrogen to the soil in the form of a nitrogen-containing chemical called *ammonia*.

In this activity, you will investigate the nitrogen cycle inside a closed system to discover how decomposers return nitrogen to the soil.

Procedure

1. Fit a piece of filter paper into a funnel. Place the funnel inside a 50 mL beaker, and pour 5 g of soil into the funnel. Add 25 mL of distilled water to the soil.
2. Test the filtered water with pH paper, and record your observations.
3. Place some soil in a jar to cover the bottom with about 5 cm of soil. Add 10 mL of distilled water to the soil.
4. Place the dead insects in the jar, and seal the jar with the lid.
5. Check the jar each day for 5 days for an ammonia odor. (If you do not know what ammonia smells like, ask your teacher.) Record your observations. **Caution:** Your teacher will demonstrate how to check for a chemical odor by wafting. Notice how to gently wave the chemical fumes toward your nose with your hand. Do not put your nose in the jar and inhale!

Copyright © by Holt, Rinehart and Winston. All rights reserved.



6. On the fifth day, place a second piece of filter paper into the funnel, and place the funnel inside a 50 mL beaker. Remove about 5 g of soil from the jar, and place it in the funnel. Add 25 mL of distilled water to the soil.

7. Once again, test the filtered water with pH paper, and record your observations.

Analyze the Results

1. **Examining Data** What was the pH of the water in the beaker in the first trial? A pH of 7 indicates that the water is neutral. A pH below 7 indicates that the water is acidic, and a pH above 7 indicates that the water is basic. Was the water in the beaker neutral, acidic, or basic?

2. **Analyzing Data** What was the pH of the water in the beaker in the second trial? Explain the difference, if any, between the results of the first trial and the results of the second trial.

Draw Conclusions

3. **Drawing Conclusions** Based on the results of your pH tests, do you think ammonia is acidic or basic?

4. **Evaluating Results** On which days in your investigation were you able to detect an ammonia odor? Explain what caused the odor.

5. **Applying Conclusions** Describe the importance of decomposers in the nitrogen cycle.

Applying Your Data

Test the importance of nitrogen to plants. Fill two 12 cm flowerpots with commercially prepared potting soil and water. Be sure to use soil that has had no fertilizer added. Obtain a dozen tomato or radish seeds. Plant six seeds in each pot. Water your seeds so that the soil is constantly damp but not soaked. Keep your pots in a sunny window. Use a nitrogen-rich liquid plant fertilizer to fertilize one of the pots once a week. Dilute or mix the fertilizer with water according to the directions on the container. Water the other pot once a week with plain tap water.

1. After the seedlings appear, use a metric ruler to measure the growth of the plants in both pots. Measure the plants once a week, and record your results.
2. You may plant other seeds of your choice, but do not use legume (bean) seeds. Research to find out why!

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Chapter Review

USING KEY TERMS

Complete each of the following sentences by choosing the correct term from the word bank.

evaporation	limiting factor
photosynthesis	decomposition
combustion	succession

1. The breakdown of dead materials into carbon dioxide and water is called ___.

2. The gradual development of a community over time is called ___.

3. During ___, the heat causes water to change from liquid to vapor.

4. ___ is the process of burning a substance.

5. ___ is the process by which plants, algae, and some bacteria make their own food.

6. A(n) ___ keeps a population from reaching its full potential.

UNDERSTANDING KEY IDEAS

Multiple Choice

7. Clouds form in the atmosphere through the process of
   - **a.** precipitation.
   - **b.** respiration.
   - **c.** condensation.
   - **d.** decomposition.

8. Mature communities
   - **a.** have low biodiversity.
   - **b.** are always forests.
   - **c.** have a high degree of biodiversity.
   - **d.** are dominated by pioneer species.

9. Burning gas in an automobile is a type of
   - **a.** combustion.
   - **b.** respiration.
   - **c.** decomposition.
   - **d.** photosynthesis.

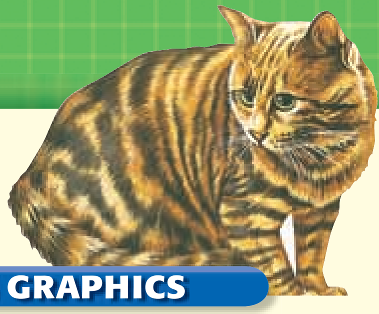
10. Nitrogen in the form of a gas can be used directly by some kinds of
    - **a.** plants.
    - **b.** animals.
    - **c.** bacteria.
    - **d.** fungi.

11. During the nitrogen cycle, bacteria are important in the process of
    - **a.** combustion.
    - **b.** condensation.
    - **c.** nitrogen fixation.
    - **d.** evaporation.

12. The pioneer species on bare rock are usually
    - **a.** ferns.
    - **b.** pine trees.
    - **c.** mosses.
    - **d.** lichens.

13. During gas exchange in plants,
    - **a.** carbon dioxide exits the leaf while oxygen and water enter the leaf.
    - **b.** oxygen and water exit the leaf while carbon dioxide enters the leaf.
    - **c.** carbon dioxide and water enter the leaf while oxygen exits the leaf.
    - **d.** carbon dioxide and oxygen enter the leaf while water exits the leaf.

Copyright © by Holt, Rinehart and Winston. All rights reserved.



Short Answer

14 Compare photosynthesis and cellular respiration.

15 List five factors that affect the survival of living organisms.

16 What are the roles of humans and animals in the carbon cycle?

17 How is water important to the survival of organisms?

18 Draw a simple diagram of the nitrogen cycle.

19 Compare the two forms of succession.

CRITICAL THINKING

20 **Concept Mapping** Use the following terms to create a concept map: *abandoned farmland, lichens, bare rock, soil formation, horseweed, succession, forest fire, primary succession, secondary succession,* and *pioneer species*.

21 **Forming Hypotheses** Predict what would happen if all of the photosynthetic organisms on Earth disappeared.

22 **Forming Hypotheses** Predict what would happen if all of the bacteria on Earth suddenly disappeared.

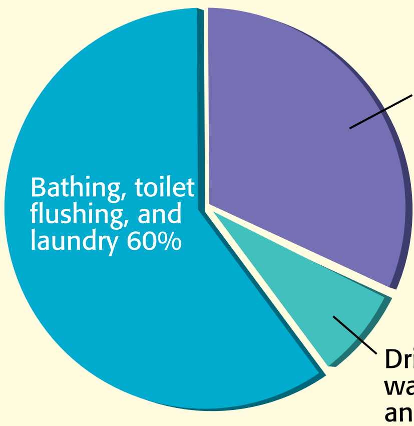
23 **Making Inferences** Describe why a lawn usually doesn't go through succession.

24 **Analyzing Ideas** Can one scientist observe all of the stages of secondary succession on an abandoned field? Explain your answer.

INTERPRETING GRAPHICS

The graph below shows how water is used each day by an average household in the United States. Use the graph to answer the questions that follow.

Average Household Daily Water Use

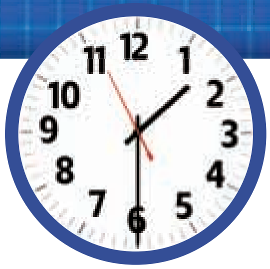


25 According to this graph, which of the following activities uses the greatest amount of water?

a. bathing
b. toilet flushing
c. washing laundry
d. There is not enough information to determine the answer.

26 A family used 380 L of water per day. Then, the family stopped washing the car, stopped watering the lawn, and stopped using the pool. Now, how much water per day does the family use?

Copyright © by Holt, Rinehart and Winston. All rights reserved.



Standardized Test Preparation

EOG Prep

READING

Read each of the passages below. Then, answer the questions that follow each passage.

Passage 1 The layer of soil above the permafrost is too shallow for plants that have deep roots to live. Grasses and shrubs can survive there because they have shallow roots. A sheet of mosses and lichens grows beneath these plants. When the soil above the permafrost thaws, the soil becomes muddy. Muddy soil is an excellent place for insects, such as mosquitoes, to lay eggs. Many birds spend the summer in the tundra to feed on these insects. Tundra animals include caribou, musk oxen, wolves, and other large mammals. Smaller animals, such as lemmings, shrews, and hares, also live in the tundra.

1. Based on the passage, what is one reason for the lack of trees on the tundra?

A Trees need more sunlight than is available.
B The roots of trees need more room than is available.
C The soil above the permafrost becomes too muddy for trees.
D Trees need more water than is available.

2. Based on the passage, which of the following statements about permafrost is true?

F Permafrost is a thawed layer of soil.
G Permafrost is always moist.
H Permafrost is always frozen.
I Permafrost is shallow.

3. Based on the passage, which of the following statements is a fact?

A Muddy soil is an excellent place for mosses and lichens to grow.
B Birds fly north to reach the tundra in the summer.
C Caribou and oxen are some of the large mammals that live in the tundra.
D The tundra is a beautiful biome that is home to diverse communities.

Passage 2 Every summer, millions of fish are killed in an area in the Gulf of Mexico called a *hypoxia region*. Hypoxia is a condition that occurs when there is an unusually low level of oxygen in the water. The area is often referred to as the *dead zone* because almost every fish and crustacean in the area dies. In 1995, this zone covered more than 18,000 km^2, and almost 1 million fish were killed in a single week. Why does this happen? Can it be stopped?

1. Based on the passage, what is the **best** definition of a *hypoxia region*?

A a region where millions of fish are killed
B a region where the level of oxygen is low
C a region that creates a "dead zone"
D a region that is 18,000 km^2

2. Why is the hypoxia region called a *dead zone*?

F because the oxygen in the region is dead
G because the region covers more area than fish can live in
H because the Gulf of Mexico is not a popular fishing zone anymore
I because almost every fish and crustacean in the area dies

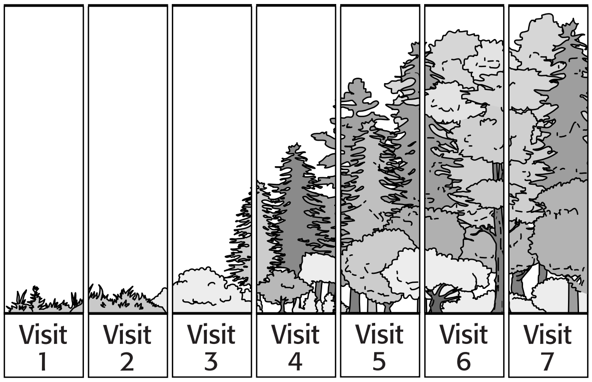
3. What information would the paragraph following the passage provide?

A an explanation of the definition of *hypoxia*
B a description of how hypoxia occurs in other parts of the world
C a list of all of the animals that died in the Gulf of Mexico in 1995
D an explanation of how the hypoxia region is formed in the Gulf of Mexico

Copyright © by Holt, Rinehart and Winston. All rights reserved.

INTERPRETING GRAPHICS

The illustration below shows what an area looked like when visited on several successive occasions. Use the illustration to answer the questions that follow.



1. In the area illustrated, what process is evident over time?

A ecological succession
B combustion of fossil fuels
C pioneer speciation
D ecological organization

2. During which of the following visits would you see the **most** mature community?

F visit 1
G visit 3
H visit 5
I visit 7

3. Assume that a forest fire happened after the seventh visit. If the scientist were to visit again within 1 year after the fire, the area would most likely look like it did during which visit?

A visit 1
B visit 3
C visit 5
D visit 7

MATH

Read each question below, and choose the best answer.

1. Flushing the toilet accounts for almost half the water a person uses in a day. Some toilets use up to 6 gal per flush. More-efficient toilets use about 1.5 gal per flush. How many liters of water can you save each day by using a more-efficient toilet if you flush five times a day? (One gallon is equal to 3.79 L.)

A 4.5 gal
B 20 gal
C 80 L
D 85 L

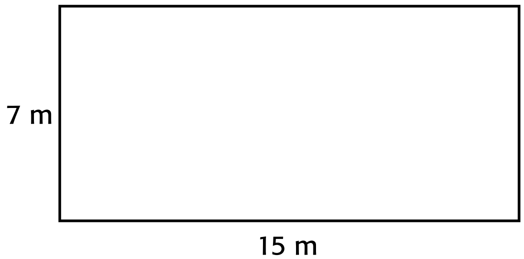
2. About 15 m of topsoil covers the eastern plains of the United States. If topsoil forms at the rate of 2.5 cm per 500 years, how long did it take for the 15 m of topsoil to form?

F 3,000 years
G 18,750 years
H 30,000 years
I 300,000 years

3. If $16 = 2x + 10$, what is x?

A 2
B 3
C 4
D 8

4. What is the area of the rectangle below?



F 22 m
G 22 m^2
H 105 m
I 105 m^2

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Science in Action

Science, Technology, and Society

Desalination

By the year 2025, it is estimated that almost a billion people on Earth will face water shortages. Only about 3% of the water on Earth is *fresh water*—the kind of water that we use for drinking and farming. And the human population is using and polluting Earth's fresh water too quickly. The other 97% of Earth's water is mostly in oceans and is much too salty for drinking or farming.

Until recently, it was very expensive and time-consuming to filter salt out of water, a process known as *desalination*. But new technologies are making desalination an affordable option for some areas.

Math ACTIVITY

You need to drink about 2 quarts of water each day. Imagine that you have a simple device that evaporates sea water and collects fresh, drinkable water at the rate of 6 mL/min. How long will it take your device to collect enough water each day?

Scientific Discoveries

The Dead Zone

Every summer, millions of fish are killed in an area in the Gulf of Mexico called a hypoxia region. *Hypoxia* (hie PAHK see uh) is a condition of water with unusually low levels of oxygen. The Gulf's hypoxia region is called a "dead zone" because a large number of organisms in the area die. Why does this happen? Scientists think that the region may be polluted with large amounts of nitrogen and phosphorus. These nutrients promote the growth of algae, which "bloom" and then die in huge numbers. When the algae is decomposed by bacteria, the bacteria use up oxygen in the water and hypoxia results. Scientists think that the polluting chemicals are washed into the Gulf by the Mississippi River. This river receives runoff from a large area that includes farms, housing, and cities. The scientists propose that adding wetlands to the Mississippi River watershed could reduce the chemicals reaching the Gulf.

Language Arts ACTIVITY

WRITING SKILL The Gulf of Mexico is not the only place where a hypoxia region exists. Research other bodies of water to find out how widespread the problem is. Write a short report telling what scientists are doing to reduce hypoxia in other places.

For several years after it was first noticed, the Gulf of Mexico hypoxia region became larger.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Careers

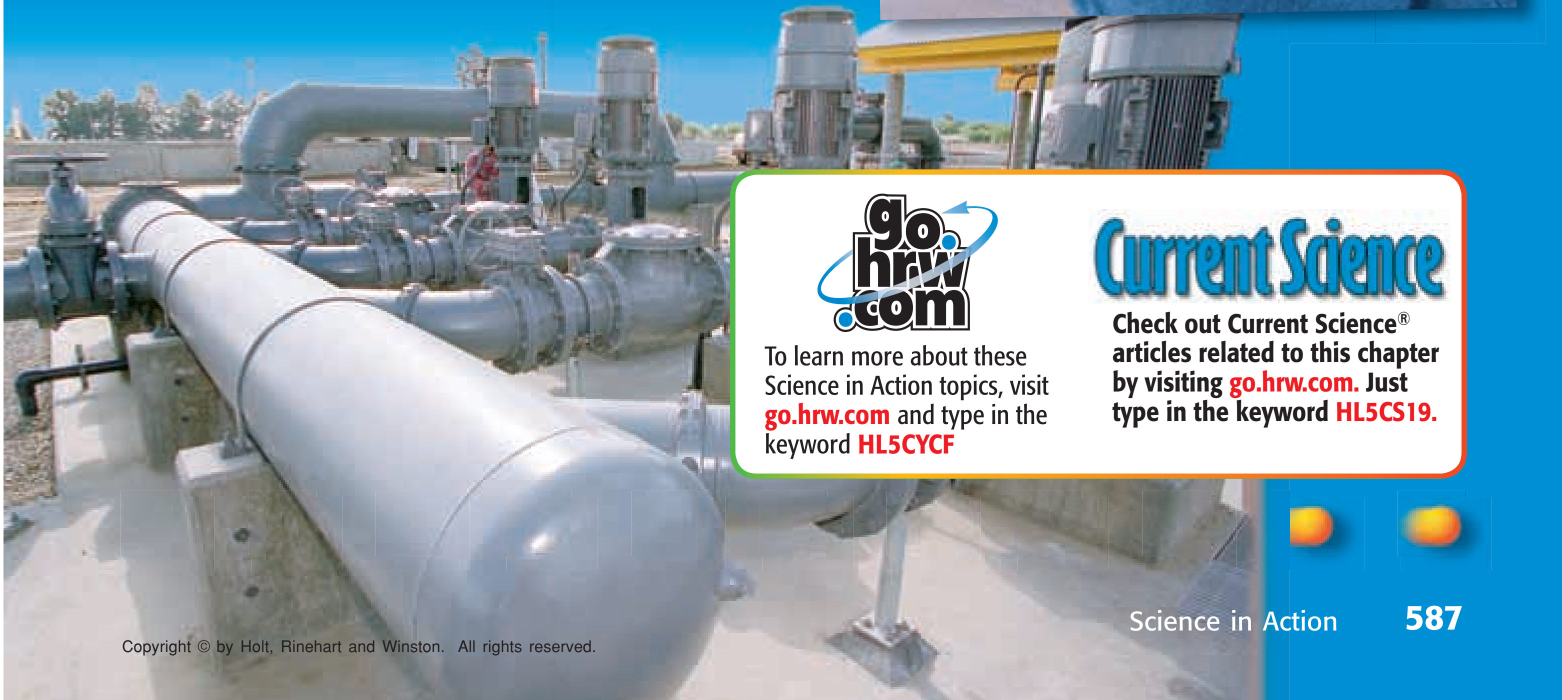
Michael Fan

Wastewater Manager If you are concerned about clean water and you like to work both in a laboratory and outdoors, you might like a career in wastewater management. The water cycle helps to keep water in nature pure enough for most organisms. But when humans use water in houses, factories, and farms, we create *wastewater*, often faster than natural processes can clean it up. To make the water safe again, we can imitate the ways water gets cleaned up in nature—and speed up the process.

Michael M. Fan is the Assistant Superintendent of wastewater operations at the Wastewater Treatment Plant at the University of California in Davis, California. This plant has one of the most advanced wastewater management systems in the country. Mr. Fan finds his job exciting. The plant operates 24 hours a day, and there are many tasks to manage. Running the plant requires skills in chemistry, physics, microbiology, and engineering. Many organisms in the Davis area are counting on Mr. Fan to make sure that the water used by the University campus is safely returned to nature.

Social Studies ACTIVITY

Research the ways that the ancient Romans managed their wastewater. Make a poster that illustrates some of their methods and technologies.



To learn more about these Science in Action topics, visit go.hrw.com and type in the keyword **HL5CYCF**

Current Science

Check out Current Science® articles related to this chapter by visiting go.hrw.com. Just type in the keyword HL5CS19.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

20

Environmental Problems and Solutions

About the PHOTO

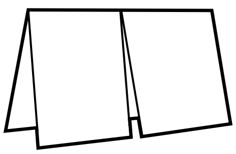
After an oil spill, volunteers try to capture oil-covered penguins. The oil affects the penguins' ability to float. So, oil-covered penguins often won't go into the water to get food. The penguins may also swallow oil, harming their stomach, kidneys, and lungs. Once captured, the penguins are fed activated charcoal. The charcoal helps the penguins get rid of any oil they have swallowed. Then, the birds are washed to remove oil from their feathers.

PRE-READING ACTIVITY

FOLDNOTES

Two-Panel Flip Chart

Before you read the chapter, create the FoldNote entitled "Two-Panel Flip Chart" described in the **Study Skills** section of the Appendix. Label the flaps of the two-panel flip chart with "Environmental problems" and "Environmental solutions." As you read the chapter, write information you learn about each category under the appropriate flap.



Copyright © by Holt, Rinehart and Winston. All rights reserved.

START-UP ACTIVITY

Recycling Paper

In this activity, you will be making paper without cutting down trees. You will be reusing paper that has already been made.

Procedure

1. Tear **two sheets of old newspaper** into small pieces, and put them in a **blender.** Add **1 L of water.** Cover and blend until the mixture is soupy.
2. Fill a **square pan** with **water** to a depth of 2 cm to 3 cm. Place a **wire screen** in the pan. Pour 250 mL of the paper mixture onto the screen, and spread the mixture evenly.
3. Lift the screen out of the water with the paper on it. Drain excess water into the pan.
4. Place the screen inside a **section of newspaper.** Close the newspaper, and turn it over so that the screen is on top of the paper mixture.
5. Cover the newspaper with a **flat board.** Press on the board to squeeze out excess water.
6. Open the newspaper, and let your paper mixture dry overnight. Use your recycled paper to write a note to a friend!

Analysis

1. How is your paper like regular paper? How is it different?
2. What could you do to improve your papermaking methods?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 1

Environmental Problems

Maybe you've heard warnings about dirty air, water, and soil. Or you've heard about the destruction of rain forests. Do these warnings mean our environment is in trouble?

READING WARM-UP

Objectives

- List four kinds of pollutants.
- Distinguish between renewable and nonrenewable resources.
- Explain why human population growth has increased.
- Describe how habitat destruction affects biodiversity.
- Give two examples of how pollution affects humans.

Terms to Learn

pollution
renewable resource
nonrenewable resource
overpopulation
biodiversity

READING STRATEGY

Reading Organizer As you read this section, make a concept map by using the terms above.

During the Industrial Revolution, which started in the late 1700s, people began to rely more and more on machines. And the human population began to grow at a much faster rate. As a result, harmful substances entered the air, water, and soil.

Pollution

There are more sources of pollution today than there once were. **Pollution** is an unwanted change in the environment caused by substances, such as wastes, or forms of energy, such as radiation. Anything that causes pollution is called a *pollutant*. Some pollutants are produced by natural events, such as volcanic eruptions. Many pollutants are human-made. Pollutants may harm plants, animals, and humans.

pollution an unwanted change in the environment caused by substances or forms of energy

Solid Wastes

As the human population grows, the amount of solid waste, or trash, that humans produce increases. This solid waste is often put in a landfill such as the one in **Figure 1.** Other kinds of landfills contain hazardous wastes. *Hazardous wastes* include wastes that can catch fire, corrode—or eat through—metal, explode, or make people sick. As the human population grows, the amount of land available for landfills decreases. So, getting rid of solid waste is becoming increasingly difficult.

Reading Check **What is hazardous waste?** (*See the Appendix for answers to Reading Checks.*)

Figure 1 *Every year, Americans throw away about 200 million metric tons of garbage.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 2 *Fertilizer promotes the growth of algae. As dead algae decompose, oxygen in the water is used up. So, fish die because they cannot get oxygen.*

Chemicals

People need and use many chemicals. Some chemicals are used to treat diseases. Other chemicals are used in plastics and preserved foods. Sometimes, the same chemicals that help people may harm the environment. As shown in **Figure 2,** fertilizers and pesticides may pollute soil and water.

CFCs and PCBs are two groups of harmful chemicals. Ozone in the upper atmosphere protects Earth from harmful ultraviolet light. CFCs destroy ozone. CFCs were used in aerosols, refrigerators, and plastics. The second group, PCBs, was once used in appliances and paints. PCBs are poisonous and may cause cancer. Today, the use of CFCs and PCBs is banned. But CFCs are still found in the atmosphere. And PCBs are still found in even the most remote areas on Earth.

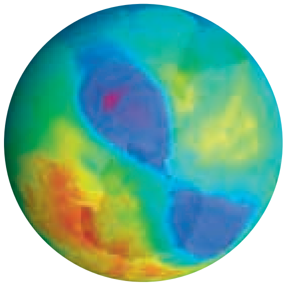
Radioactive Wastes

Nuclear power plants provide electricity to many homes and businesses. The plants also produce radioactive wastes. *Radioactive wastes* are hazardous wastes that give off radiation. Some of these wastes take thousands of years to become harmless.

Gases

Earth's atmosphere is made up of a mixture of gases, including carbon dioxide. The atmosphere acts as a protective blanket. It keeps Earth warm enough for life to exist. Since the Industrial Revolution, however, the amount of carbon dioxide in the atmosphere has increased. Carbon dioxide and other air pollutants act like a greenhouse, trapping heat around the Earth. Many scientists think the increase in carbon dioxide has increased global temperatures. If temperatures continue to rise, the polar icecaps could melt. Then, the level of the world's oceans would rise. Coastal areas could flood as a result.

CONNECTION TO Chemistry



Ozone Holes This image of two holes in the ozone layer (the purple areas over Antarctica) was taken in 2002. Ozone in the stratosphere absorbs most of the ultraviolet light that comes from the sun. Ozone is destroyed by CFCs. Research how CFCs destroy ozone. Make a model demonstrating this process. Then, identify the effects of too much ultraviolet light.

ACTIVITY

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Resource Depletion

renewable resource a natural resource that can be replaced at the same rate at which the resource is consumed

nonrenewable resource a resource that forms at a rate that is much slower than the rate at which it is consumed

Some of Earth's resources are renewable. But other resources are nonrenewable. A **renewable resource** is one that can be used over and over. Solar and wind energy are renewable resources, as are some kinds of trees. A **nonrenewable resource** is one that cannot be replaced or that can be replaced only over thousands or millions of years. Most minerals and fossil fuels, such as oil and coal, are nonrenewable resources.

Supplies of nonrenewable resources are limited. As the human population grows, it needs more of these resources. Resources will become more expensive as they become harder to find. Also, some methods of obtaining nonrenewable resources can harm the environment. Such methods may cause pollution, habitat loss, and damage from mining, as shown in **Figure 3.**

MATH PRACTICE

Water Depletion

In one day, millions of liters of water are removed from a water supply. Of this volume, 30 million liters cannot be replaced naturally. Today, the water supply has 60 billion liters of water. In years, how long would the water supply last if water continued to be removed at this rate? If water were removed at the same rate as it was replaced, how long would the water supply last?

Soil

Farming, mining, and other human activities can harm soil. Almost all farming methods increase erosion. *Erosion* is the wearing away of soil by wind or water. Erosion is a natural process. But too much erosion can cause the loss of land. Also, some farming practices deplete soil nutrients. Without these nutrients, many plants and crops cannot survive.

Water

Some resources once thought to be renewable are becoming nonrenewable. For example, fresh water was once considered a renewable resource. However, in some areas, human population growth and agriculture have had an impact on water supplies. Some of these supplies are being used faster than they are being replaced. Eventually, these areas may run out of fresh water.

Figure 3 *This area has been mined for iron using a method called strip mining.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

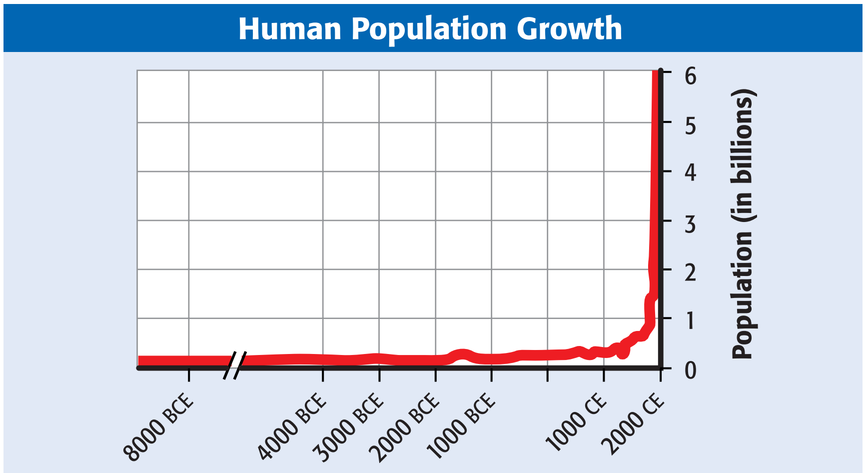


Figure 4 *Recently, the human population has been doubling every few decades.*

Human Population Growth

Look at **Figure 4.** By 2000, more than 6 billion people lived on Earth. Medical advances, such as immunizations, and advances in farming made human population growth possible. Overall, these advances are beneficial. But some people argue that there may eventually be too many people on Earth. **Overpopulation** happens when there are so many individuals in an area that the individuals can't get what they need to survive. Overpopulation can happen to any species, even humans. Overpopulation leads to resource depletion, starvation, and the spread of disease.

overpopulation the presence of too many individuals in an area for the available resources

Getting Food

As the human population grows, feeding everyone without harming the environment becomes more difficult. More food is needed each year to feed the growing human population. So, many natural areas are replaced with farmland. Today, humans produce enough food for everyone on Earth. But some areas do not get enough of this food. Eventually, these food shortages may become more widespread as the human population grows. Droughts and floods may also decrease food production in some areas.

Moving People

As you can see in **Figure 5,** people are always on the move—they're going to work, visiting family, or taking trips to the store. Getting people from one place to another requires natural resources. As more people move around, more of these resources are needed. Some of these resources, such as fossil fuels, are nonrenewable. And using some of these resources contributes to pollution.

Figure 5 *Each day, millions of people use public transportation to get from one place to another.*

Reading Check **What effect can people on the move have on the environment?**

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 6 *Deforestation can leave soil exposed to erosion.*

Habitat Destruction

People need homes. People also need food and building materials. But when land is cleared for construction, crops, mines, or lumber, soil may erode. Chemicals may pollute nearby streams and rivers. The organisms that were living in these areas may be left without food and shelter. These organisms may die.

An organism's *habitat* is where it lives. Every habitat has its own number and variety of organisms, or **biodiversity.** If a habitat is damaged or destroyed, biodiversity is lost.

biodiversity the number and variety of organisms in a given area during a specific period of time

Forest Habitats

Trees provide humans with oxygen, lumber, food, rubber, and paper. For some of these products, such as lumber and paper, trees must be cut down. *Deforestation* is the clearing of forest lands, as shown in **Figure 6.** At one time, many of these cleared forests were not replanted. Today, lumber companies often plant new trees to replace the trees that were cut down. However, few of the organisms once found in the area can be replaced. So, some biodiversity is still lost.

Tropical rain forests, the most diverse habitats on Earth, are sometimes cleared for farmland, roads, and lumber. But after a tropical rain forest is cleared, the area cannot grow to be as diverse as it once was. Also, thin tropical soils are often badly damaged.

CONNECTION TO Social Studies

Wood Identify a country that is a major exporter of wood. List some of the ways this wood is used. Research the impact this exportation is having on that country's forests. Make a poster describing your findings.

ACTIVITY

Marine Habitats

Many people think of oil spills when they think of pollution in marine habitats. This is an example of *point-source pollution*, or pollution that comes from one source. Spilled oil pollutes both open waters and coastal habitats.

A second kind of water pollution is *nonpoint-source pollution*. This kind of pollution comes from many sources. It is often difficult to identify the sources of nonpoint-source pollution. Nonpoint-source pollution can happen when chemicals on land are washed into rivers, lakes, and oceans. These chemicals may harm many of the organisms that live in marine habitats.

In addition to oil and chemicals, plastics are sometimes dumped into marine habitats. Animals may mistake plastics for food. Or animals may become tangled in plastics. Dumping plastics into the ocean is against the law. However, this law is difficult to enforce.

Reading Check **What are point-source and nonpoint-source pollution?**

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Effects on Humans

Pollution and habitat destruction not only harm plants and animals. Pollution and habitat destruction can harm humans, too. Polluted air affects people who have respiratory problems. Polluted water can make people sick. Some chemicals cause cancers many years after a person is exposed to them.

Environmental problems can affect the economies and policies of many nations. Pollution is expensive to clean up. Some polluted areas may be unsuitable for people to live in. Resources may cost more because they are hard to find. Reduced food production due to pollution and erosion can cause starvation and disease. By monitoring the environment and taking steps to protect it, people can prevent many of these problems.

SECTION Review

Summary

- Pollutants include solid wastes, chemicals, radioactive wastes, and gases.
- Renewable resources can be used over and over. Nonrenewable resources cannot be replaced or are replaced over thousands or millions of years.
- Overpopulation happens when a population is so large that it can't get what it needs to survive.
- Habitat destruction can lead to soil erosion, water pollution, and decreased biodiversity.
- In addition to harming the environment, pollution can harm humans and economies.

Using Key Terms

The statements below are false. For each statement, replace the underlined term to make a true statement.

1. Coal is a <u>renewable resource</u>.
2. <u>Overpopulation</u> is the number and variety of organisms in an area.

Understanding Key Ideas

3. Which of the following can cause pollution?
   - **a.** gases
   - **b.** solid wastes
   - **c.** chemicals
   - **d.** All of the above
4. Pollution
   - **a.** does not affect humans.
   - **b.** can affect economies.
   - **c.** makes humans sick only after many years.
   - **d.** None of the above
5. Compare renewable and nonrenewable resources.
6. Why has human population growth increased?
7. How does habitat destruction affect biodiversity?

Math Skills

8. Jodi's family produces 48 kg of garbage each week. What is the percentage decrease if they reduce the amount of garbage to 40 kg per week?

Critical Thinking

9. **Applying Concepts** Explain how each of the following can help people but harm the environment: hospitals, old refrigerators, and road construction.
10. **Making Inferences** Explain how human population growth is related to pollution problems.
11. **Predicting Consequences** How can the pollution of marine habitats affect humans?

SCILINKS® NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Air Pollution; Resource Depletion
SciLinks code: HSM0033; HSM1304

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 2

Environmental Solutions

As the human population grows, it will need more resources. People will need food, healthcare, transportation, and waste disposal. What does this mean for the Earth?

READING WARM-UP

Objectives

- Explain the importance of conservation.
- Describe the three Rs.
- Explain how biodiversity can be maintained.
- List five environmental strategies.

Terms to Learn

conservation
recycling

READING STRATEGY

Discussion Read this section silently. Write down questions that you have about this section. Discuss your questions in a small group.

All of these needs will have an impact on the Earth. If people don't use resources wisely, people will continue to pollute the air, soil, and water. More natural habitats could be lost. Many species could die out as a result. But there are many things people can do to protect the environment.

Conservation

One way to care for the Earth is through conservation (KAHN suhr VAY shuhn). **Conservation** is the preservation and wise use of natural resources. If you ride your bike instead of riding in a car, you conserve fuel. At the same time, you prevent air pollution. You can use organic compost instead of chemical fertilizer in your garden. Doing so conserves the resources needed to make the fertilizer. Also, you may reduce soil and water pollution.

Practicing conservation means using fewer natural resources. Conservation helps reduce waste and pollution. Also, conservation can help prevent habitat destruction. The three Rs are shown in **Figure 1.** They describe three ways to conserve resources: **R**educe, **R**euse, and **R**ecycle.

conservation the preservation and wise use of natural resources

Reading Check **What are the three Rs?** (*See the Appendix for answers to Reading Checks.*)

Figure 1 *By reducing, reusing, and recycling, these teens are conserving resources.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Reduce

What is the best way to conserve Earth's natural resources? Use less of them! Doing so helps reduce waste and pollution.

Reducing Waste and Pollution

As much as one-third of the waste produced by some countries is packaging material. Products can be wrapped in less paper and plastic to reduce waste. For example, fast-food restaurants used to serve sandwiches in large plastic containers. Today, sandwiches are usually wrapped in thin paper instead. This paper is more biodegradable than plastic. Something that is *biodegradable* can be broken down by living organisms, such as bacteria. Many plastics are now biodegradable. So, they break down more quickly than plastics once did.

Many people and companies are using less-hazardous materials in making their products. For example, some farmers don't use synthetic chemicals on their crops. Instead, they practice organic farming. They use mulch, compost, manure, and natural pest control. Agricultural specialists are also working on farming techniques that are better for the environment.

Reducing the Use of Nonrenewable Resources

Some scientists are looking for sources of energy that can replace fossil fuels. For example, solar energy can be used to power homes, such as the home shown in **Figure 2.** Scientists are studying power sources such as wind, tides, and falling water. Car companies have developed electric and hydrogen-fueled automobiles. Driving these cars uses fewer fossil fuels and produces less pollution than driving gas-fueled cars does.

CONNECTION TO Social Studies

Technology Explore how people solve problems related to human population growth. Examine how people deal with waste disposal, food production, resource availability, transportation, and the effects of population growth on economies. If possible, describe how technology has affected the ways in which people deal with these problems. Make a poster about your findings.

Figure 2 *The people who live in this home use solar panels to get energy from the sun.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 3 *This home was built with reused tires and aluminum cans.*

Reuse

Do you get hand-me-down clothes from an older sibling? Do you try to fix broken sports equipment instead of throwing it away? If so, you are helping conserve resources by *reusing* products.

Reusing Products

Every time you reuse a plastic bag, one bag fewer needs to be made. Reusing the plastic bag at the grocery store is just one way to reuse the bag. Reusing products is an important way to conserve resources.

You might be surprised at how many materials can be reused. For example, building materials can be reused. Wood, bricks, and tiles can be used in new structures. Old tires can be reused, too. They can be reused for playground surfaces. As shown in **Figure 3,** some tires are even reused to build new homes!

Figure 4 *This golf course is being watered with reclaimed water.*

Reusing Water

About 100 billion liters of water are used each day in American homes. Most of this water goes down the drain. Many communities are experiencing water shortages. Some of these communities are experimenting with reusing, or reclaiming, wastewater.

One way to reclaim water is to use organisms to clean the water. These organisms include plants and filter-feeding animals, such as clams. Often, reclaimed water isn't pure enough to drink. But it can be used to water crops, lawns, and golf courses, such as the one shown in **Figure 4.** Sometimes, reclaimed water is returned to underground water supplies.

✓ Reading Check **Describe how water is reused.**

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Recycle

Another example of reuse is recycling. **Recycling** is the recovery of materials from waste. Sometimes, recyclable items, such as paper, are used to make the same kinds of products. Other recyclable items are made into different products. For example, yard clippings can be recycled into a natural fertilizer.

recycling the process of recovering valuable or useful materials from waste or scrap

Recycling Trash

Plastics, paper, aluminum, wood, glass, and cardboard are examples of materials that can be recycled. Every week, about half a million trees are used to make Sunday newspapers. Recycling newspapers could save millions of trees. Recycling aluminum saves 95% of the energy needed to change raw ore into aluminum. Glass can be recycled over and over again to make new bottles and jars.

Many communities make recycling easy. Some cities provide containers for glass, plastic, aluminum, and paper. People can leave these containers on the curb. Each week, the materials are picked up for recycling, as shown in **Figure 5.** Other cities have centers where people can take materials for recycling.

Figure 5 *In some communities, recyclable materials are picked up each week.*

Recycling Resources

Waste that can be burned can also be used to generate electricity. Electricity is generated in waste-to-energy plants, such as the one shown in **Figure 6.** Using solid waste to make electricity is an example of *resource recovery.* Some companies are beginning to make electricity with their own waste. Doing so saves the companies money and conserves resources.

About 16% of the solid waste in the United States is burned in waste-to-energy plants. But some people are concerned that these plants pollute the air. Other people worry that the plants reduce recycling.

Figure 6 *A waste-to-energy plant can provide electricity to many homes and businesses.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 7 *What could happen if a fungus attacks a banana field? Biodiversity is low in fields of crops such as bananas.*

Maintaining Biodiversity

You know the three Rs. What else can you do to help the environment? You can help maintain biodiversity! So, how does biodiversity help the environment?

Imagine a forest that has only one kind of tree. If a disease hit that species, the entire forest might die. Now, imagine a forest that has 10 species of trees. If a disease hits one species, 9 other species will remain. Bananas, shown in **Figure 7,** are an important crop. But banana fields are not very diverse. Fungi threaten the survival of bananas. Farmers often use chemicals to control fungi. Growing other plants among the bananas, or increasing biodiversity, can also prevent the spread of fungi.

Biodiversity is also important because each species has a unique role in an ecosystem. Losing one species could disrupt an entire ecosystem. For example, if an important predator is lost, its prey will multiply. The prey might eat the plants in an area, keeping other animals from getting food. Eventually, even the prey won't have food. So, the prey will starve.

Protecting Species

One way to maintain biodiversity is to protect individual species. In the United States, a law called the *Endangered Species Act* was designed to do just that. Endangered species are put on a special list. The law forbids activities that would harm a species on this list. The law also requires the development of recovery programs for each endangered species. Some endangered species, such as the California condor in **Figure 8,** are now increasing in number.

Anyone can ask the government to add a species to or remove a species from the endangered species list. This process often takes more than a year to complete. The government must study the species and its habitat before making a decision.

Figure 8 *Thanks to captive-breeding programs, the California condor population is increasing.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Protecting Habitats

Waiting until a species is almost extinct to begin protecting it is like waiting until your teeth are rotting to begin brushing them. Scientists want to prevent species from becoming endangered and from becoming extinct.

Plants, animals, and microorganisms depend on each other. Each organism is part of a huge, interconnected web of organisms. The entire web should be protected to protect these organisms. To protect the web, complete habitats, not just individual species, must be preserved. Nature preserves, such as the one shown in **Figure 9,** are one way to protect entire habitats.

Figure 9 *Setting aside public lands for wildlife is one way to protect habitats.*

Environmental Strategies

Laws have been passed to help protect the Earth's environment. By following those laws, people can help the environment. People can also use the following environmental strategies:

- **Reduce pollution.** Recycle as much as possible, and buy recycled products. Don't dump wastes on farmland, in forests, or into rivers, lakes, and oceans. Participate in a local cleanup project.
- **Reduce pesticide use.** Use only pesticides that are targeted specifically for harmful insects. Avoid pesticides that might harm beneficial insects, such as ladybugs or spiders. Use natural pesticides that interfere with how certain insects grow, develop, and reproduce.
- **Protect habitats.** Preserve entire habitats. Conserve wetlands. Reduce deforestation. Use resources at a rate that allows them to be replenished naturally.
- **Learn about local issues.** Attend local meetings about laws and projects that may affect your local environment. Research the impact of the project, and let people know about your concerns.
- **Develop alternative energy sources.** Increase the use of renewable energy, such as solar power and wind power.

The *Environmental Protection Agency* (EPA) is a government organization that helps protect the environment. The EPA works to help people have a clean environment in which to live, work, and play. The EPA keeps people informed about environmental issues and helps enforce environmental laws.

Reading Check What is the EPA?

INTERNET ACTIVITY

For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HL5ENVW.**

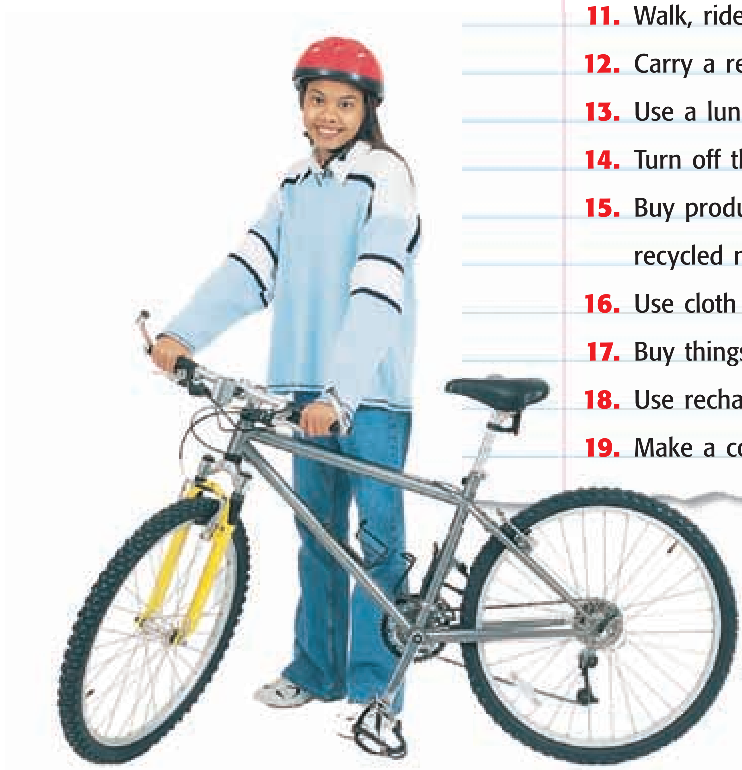
Copyright © by Holt, Rinehart and Winston. All rights reserved.

What You Can Do

Reduce, reuse, and recycle—these are jobs for everyone. People need to monitor their environment to make sure it stays healthy. People need to take steps to maintain air, water, and soil quality. And people need to practice *stewardship*, or the careful use of resources. The list in **Figure 10** offers some suggestions for how *you* can help. How many of these things do you already do? What can you add to the list?

Figure 10 **How You Can Help the Environment**

1. Volunteer at a local preserve or nature center, and help other people learn about conservation.
2. Give away your old toys.
3. Use recycled paper.
4. Fill up both sides of a sheet of paper.
5. Start an environmental awareness club at your school or in your neighborhood.
6. Recycle glass, plastics, paper, aluminum, and batteries.
7. Don't buy any products made from an endangered plant or animal.
8. Turn off electrical devices when you are not using them.
9. Wear hand-me-downs.
10. Share books with friends, or use the library.
11. Walk, ride a bicycle, or use public transportation.
12. Carry a reusable cloth shopping bag to the store.
13. Use a lunch box, or reuse your paper lunch bags.
14. Turn off the water while you brush your teeth.
15. Buy products made from biodegradable and recycled materials.
16. Use cloth napkins and kitchen towels.
17. Buy things in packages that can be recycled.
18. Use rechargeable batteries.
19. Make a compost heap.



Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION Review

Summary

- Conservation is the preservation and wise use of natural resources. Conservation helps reduce pollution, ensures that resources will be available in the future, and protects habitats.
- The three Rs are Reduce, Reuse, and Recycle. Reducing means using fewer resources. Reusing means using materials and products over and over. Recycling is the recovery of materials from waste.
- Biodiversity is vital for maintaining healthy ecosystems. A loss of one species can affect an entire ecosystem.
- Biodiversity can be preserved by protecting endangered species and entire habitats.
- Environmental strategies include reducing pollution, reducing pesticide use, protecting habitats, enforcing the Endangered Species Act, and developing alternative energy resources.

Using Key Terms

1. Use each of the following terms in a separate sentence: *conservation* and *recycling*.

Understanding Key Ideas

2. Which of the following is NOT a strategy to protect the environment?
   a. preserving entire habitats
   b. using pesticides that target all insects
   c. reducing deforestation
   d. increasing the use of solar power
3. Conservation
   a. has little effect on the environment.
   b. is the use of more natural resources.
   c. involves using more fossil fuels.
   d. can prevent pollution.
4. Describe the three Rs.
5. Describe why biodiversity is important. How can biodiversity be protected?

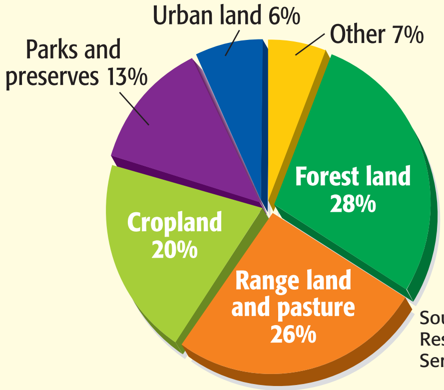
Critical Thinking

6. **Applying Concepts** Liza rode her bike to the store. She bought items that had little packaging and put her purchases into her backpack. Describe how Liza practiced conservation.
7. **Identifying Relationships** How does conservation of resources also reduce pollution and protect habitats?

Interpreting Graphics

Use the pie graph below to answer the questions that follow.

Land Use in the United States



Source: Natural Resources Conservation Service.

8. If half of the forest land were made into preserves, what percentage of total land would be parks and preserves?
9. If 10% of the cropland were not planted, what percentage of land would be used for crops?

SCILINKS® NSTA
Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Recycling; Maintaining Biodiversity
SciLinks code: HSM1277; HSM0902

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Using Scientific Methods

Inquiry Lab

OBJECTIVES

Examine biodiversity in your community.

Identify which areas in your community have the greatest biodiversity.

MATERIALS

- items to be determined by the students and approved by the teacher (Possible field equipment includes a meterstick, binoculars, a magnifying lens, and forceps.)
- stakes (4)
- twine

SAFETY

Biodiversity—What a Disturbing Thought!

Biodiversity is important for the stability of an ecosystem. Microorganisms, plants, and animals all have a role in an ecosystem. In this activity, you will investigate areas outside your school to determine which areas contain the greatest biodiversity.

Ask a Question

1. Based on your understanding of biodiversity, do you expect a forest or an area planted with crops to be more diverse?

Form a Hypothesis

2. Select an area that is highly disturbed (such as a yard) and an area that is relatively undisturbed (such as a vacant lot). Make a hypothesis about which area contains the greater biodiversity. Get your teacher's approval of your selected locations.

Test the Hypothesis

3. Design a procedure to determine which area contains the greater biodiversity. Have your plan approved by your teacher before you begin.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Prairie

Wheat Field

4. To discover smaller organisms, measure off a square meter, set stakes at the corners, and mark the area with twine. Use a magnifying lens to observe organisms. When you record your observations, refer to organisms in the following way: Ant A, Ant B, and so on. Make note of any visits by larger organisms.

5. Create any data tables that you might need for recording your data. If you observe your areas on more than one occasion, make data tables for each observation period. Organize your data into clear and understandable categories.

Analyze the Results

1. **Explaining Events** What factors did you consider before deciding which habitats were disturbed or undisturbed?

2. **Constructing Maps** Draw a map of the land around your school. Label areas of high biodiversity and those of lower biodiversity.

3. **Analyzing Data** What problems did you have while making observations and recording data for each habitat? How did you solve these problems?

Draw Conclusions

4. **Drawing Conclusions** Review your hypothesis. Did your data support your hypothesis? Explain your answer.

5. **Evaluating Methods** Describe possible errors in your investigation. What are ways you could improve your procedure to eliminate errors?

6. **Applying Conclusions** Do you think that the biodiversity around your school increased or decreased since the school was built? Explain your answer.

Applying Your Data

The photographs of the prairie and of the wheat field on this page are beautiful. One of these areas, however, is very low in biodiversity. Describe each photograph, and explain the difference in biodiversity.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Chapter Review

USING KEY TERMS

Complete each of the following sentences by choosing the correct term from the word bank.

conservation
pollution
recycling
biodiversity
overpopulation
renewable resource
nonrenewable resource

1. A(n) ___ is a resource that is replaced at a much slower rate than it is used.

2. The presence of too many individuals in a population for available resources is called ___.

3. ___ is an unwanted change in the environment caused by wastes.

4. The preservation and wise use of natural resources is called ___.

5. ___ is the number and variety of organisms in an area.

UNDERSTANDING KEY IDEAS

Multiple Choice

6. Preventing habitat destruction is important because
   a. organisms do not live independently of each other.
   b. protection of habitats is a way to promote biodiversity.
   c. the balance of nature could be disrupted if habitats were destroyed.
   d. All of the above

7. Which of the following is NOT true about soil erosion?
   a. Soil erosion is a natural process.
   b. Soil erosion is increased by very few farming methods.
   c. Soil erosion can cause land loss.
   d. Soil erosion is the wearing away of soil by wind or water.

8. A renewable resource
   a. is a natural resource that can be replaced as quickly as it is used.
   b. is a natural resource that takes thousands or millions of years to be replaced.
   c. includes fossil fuels, such as coal or oil.
   d. will eventually run out.

Short Answer

9. Describe how you can use the three Rs to conserve resources.

10. What are four kinds of pollutants?

11. Explain why human population growth has increased.

12. What are two things that can be done to maintain biodiversity?

13. List five environmental strategies.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

CRITICAL THINKING

14 **Concept Mapping** Use the following terms to create a concept map: *pollution, radioactive wastes, gases, pollutants, CFCs, PCBs, hazardous wastes, chemicals, noise,* and *garbage*.

15 **Analyzing Ideas** How may deforestation have contributed to the extinction of some species?

16 **Predicting Consequences** Imagine that the supply of fossil fuels is going to run out in 50 years. What will happen if people are not prepared when the supply runs out? What might be done to prepare for such an event?

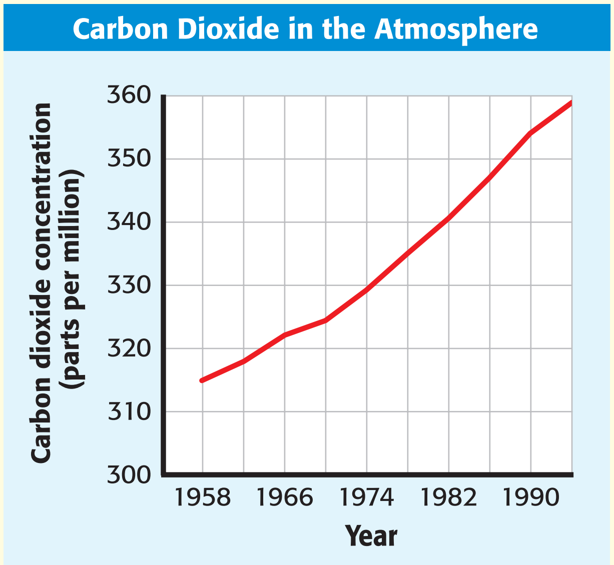
17 **Evaluating Conclusions** A scientist thinks that farms should be planted with many different kinds of crops instead of a single crop. Based on what you learned about biodiversity, evaluate the scientist's conclusion. What problems might this cause?

18 **Applying Concepts** As the human population grows, more land likely will be needed to grow food. What kind of impact can this need for more food have on the environment?

19 **Making Inferences** Many scientists think that forests are nonrenewable resources. Explain why they might have this opinion.

INTERPRETING GRAPHICS

The line graph below shows the concentration of carbon dioxide in the atmosphere between 1958 and 1994. Use this graph to answer the questions that follow.

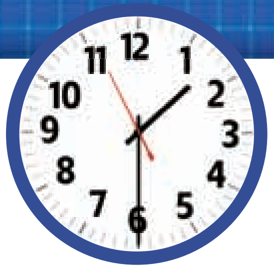


20 What was the concentration of carbon dioxide in parts per million in 1960? in 1994?

21 What is the average change in carbon dioxide concentration every 4 years?

22 If the concentration of carbon dioxide continues to change at the rate shown in the graph, what will the concentration be in 2010?

Copyright © by Holt, Rinehart and Winston. All rights reserved.



Standardized Test Preparation

EOG Prep

READING

Read the passages below. Then, answer the questions that follow each passage.

Passage 1 The scientist woke up and jogged over to the rain forest. There she observed the water-recycling experiment. She took a swim in the ocean, after which she walked through a mangrove forest on her way home. At home, she ate lunch and went to the computer lab. From the lab, she could monitor the sensors that would alert her if any part of the ecosystem failed to cycle properly. This monitoring was very important to the scientist and her research team because their lives depended on the health of their sealed environment.

1. Based on the passage, the reader can conclude which of the following?

A The scientist lives in an artificial environment.
B The scientist lives by herself.
C The scientist and her research team are studying a newly discovered island.
D The scientist does not rely on the health of her environment.

2. Which of the following statements is a fact in the passage?

F The scientist is scared that her environment is being destroyed.
G The scientist depends on sensors to alert her to trouble.
H The scientist lives in an open environment.
I The scientist eats lunch at home every day.

3. Based on the passage, which of the following events happened first?

A The scientist walked through the mangrove forest.
B The scientist checked the water-recycling experiment.
C The scientist swam in the ocean.
D The scientist ate lunch.

Passage 2 All along the Gulf Coast, marine scientists and Earth scientists are trying to find methods to reduce or eliminate the dead zone. They have made models of the Mississippi River ecosystem that have accurately predicted the data that have since been collected. The scientists have changed the models to see what happens. For example, wetlands are one of nature's best filters. Wetlands take up a lot of the chemicals present in water. Scientists predict that adding wetlands to the Mississippi River watershed could reduce the chemicals reaching the Gulf of Mexico, possibly reducing the dead zone.

1. Based on the passage, what can you conclude about the dead zone?

A It is found in the Mississippi River.
B It may be prevented by adding wetlands to the Mississippi River watershed.
C It reduces the chemicals reaching the Gulf of Mexico.
D It is not caused by chemicals.

2. Based on the passage, which of the following statements about models is true?

F Models do not accurately predict data.
G Scientists do not change models.
H Scientists use models to make predictions.
I Models are always used for research.

3. Based on the passage, why did the scientists change their models?

A to predict the effects of adding wetlands to the Mississippi River watershed
B to find out why the dead zone happened
C to eliminate the dead zone
D to predict why there are a lot of chemicals in the Gulf of Mexico

Copyright © by Holt, Rinehart and Winston. All rights reserved.

INTERPRETING GRAPHICS

The table below shows the change in ozone levels between 1960 and 1990 above Halley Bay, Antarctica. Use the table to answer the questions that follow.

October Ozone Levels Above Halley Bay, Antarctica, in Dobson Units (DU)

Year	Ozone level (DU)
1960	300
1970	280
1980	235
1990	190

1. According to the table, which of the following is the most likely ozone level for October 2000?

A 120 DU
B 150 DU
C 235 DU
D 280 DU

2. According to the table, the ozone level above Halley Bay is doing which of the following?

F It steadily increased between 1960 and 1990.
G It fell by 37% between 1960 and 1990.
H It decreased by an average of 37 DU per year.
I It decreased by about 25% every 10 years.

3. What is the percent decrease in ozone level between 1980 and 1990?

A 16%
B 19%
C 24%
D 81%

4. What is the average loss of ozone level per year in DU?

F 4 DU
G 6 DU
H 37 DU
I 63 DU

MATH

Read each question below, and choose the best answer.

1. About 15 m of topsoil covers the western plains of the United States. If topsoil forms at the rate of 2.5 cm per 500 years, how long did it take for 15 m of topsoil to form?

A 3,000 years
B 7,500 years
C 18,750 years
D 300,000 years

2. The dimensions of a habitat are 16 km by 6 km. If these dimensions are decreased by 50%, what will the area of the habitat be?

F 22 km^2
G 24 km^2
H 48 km^2
I 96 km^2

3. If each person in a city of 500,000 people throws away 12 kg of trash each week, how many metric tons of trash does the city produce per year? (There are 1,000 kg in a metric ton.)

A 6,000 metric tons
B 26,000 metric tons
C 312,000 metric tons
D 312,000,000 metric tons

4. Producing one ton of new glass creates about 175 kg of mining waste. Using 50% recycled glass cuts this rate by 75%. Which of the following equations calculates *y*, the mass of mining waste produced using 50% recycled glass?

F $y = 175 \times 0.25$
G $y = 175 \times 0.75$
H $y = 175 \times 0.5$
I $y = 175 \div 0.75$

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Science in Action

Scientific Debate

Where Should the Wolves Roam?

The U.S. Fish and Wildlife Service once listed the gray wolf as an endangered species and devised a plan to reintroduce the wolf to parts of the U.S. The goal was to establish a population of at least 100 wolves at each location. In April 2003, gray wolves were reclassified as a threatened species in much of the United States. Eventually, gray wolves may be removed from the endangered species list entirely. But some ranchers and hunters are uneasy about the reintroduction of gray wolves, and some environmentalists and wolf enthusiasts think the plan doesn't go far enough to protect wolves.

Math ACTIVITY

Scientists tried to establish a population of 100 wolves in Idaho. But the population grew to 285 wolves. By what percentage did the population exceed expectations?

Science, Technology, and Society

Hydrogen-Fueled Automobiles

Can you imagine a car that purrs quieter than a kitten and gives off water vapor instead of harmful pollutants? These cars may sound like science fiction. But such cars already exist! They run on one of the most common elements in the world—hydrogen. Some car companies are already speculating that one day all cars will run on hydrogen. The U.S. government has also taken notice. In 2003, President George W. Bush promised $1.2 billion to help research and develop hydrogen-fueled cars.

Language Arts ACTIVITY

WRITING SKILL Research hydrogen-fueled cars. Then, write a letter to a car company, your senator, or the President expressing your opinion about the development of hydrogen-fueled cars.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

People in Science

Phil McCrory

Hairy Oil Spills Phil McCrory, a hairdresser in Huntsville, Alabama, asked a brilliant question when he saw an otter whose fur was drenched with oil from the *Exxon Valdez* oil spill. If the otter's fur soaked up all the oil, why wouldn't human hair do the same? McCrory gathered hair from the floor of his salon and took it home to perform his own experiments. He stuffed hair into a pair of his wife's pantyhose and tied the ankles together to form a bagel-shaped bundle. McCrory floated the bundle in his son's wading pool and poured used motor oil into the center of the ring. When he pulled the ring closed, not a drop of oil remained in the water!

McCrory approached the National Aeronautics and Space Administration (NASA) with his discovery. Based on tests performed by NASA, scientists estimated that 64 million kilograms of hair in reusable mesh pillows could have cleaned up all of the oil spilled by the *Exxon Valdez* within a week! Unfortunately, the $2 billion spent on the cleanup removed only about 12% of the oil.

Social Studies ACTIVITY

Make a map of an oil spill. Show the areas that were affected. Indicate some of the animal populations affected by the spill, such as penguins.

go.hrw.com

To learn more about these Science in Action topics, visit go.hrw.com and type in the keyword HL5ENVF.

Current Science

Check out Current Science® articles related to this chapter by visiting go.hrw.com. Just type in the keyword HL5CS21.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

21

The Evolution of Living Things

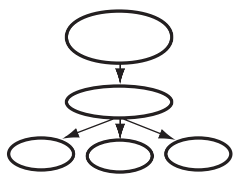
About the PHOTO

What happened to this fish's face? This flounder wasn't born this way, but it did develop naturally. When young, a flounder looks and swims as most fish do. But as it becomes an adult, one of its eyes moves to the other side of its head, and the flounder begins to swim sideways. An adult flounder is adapted to swim and hide along the sandy bottom of coastal areas.

PRE-READING ACTIVITY

Graphic Organizer

Concept Map Before you read the chapter, create the graphic organizer entitled "Concept Map" described in the **Study Skills** section of the Appendix. As you read the chapter, fill in the concept map with details about evolution and natural selection.



Copyright © by Holt, Rinehart and Winston. All rights reserved.

START-UP ACTIVITY

Out of Sight, Out of Mind

In this activity, you will see how traits can affect the success of an organism in a particular environment.

Procedure

1. Count out **25 colored marshmallows** and **25 white marshmallows.**
2. Ask your partner to look away while you spread the marshmallows out on a **white cloth.** Do not make a pattern with the marshmallows. Now, ask your partner to turn around and pick the first marshmallow that he or she sees.
3. Repeat step 2 ten times.

Analysis

1. How many white marshmallows did your partner pick? How many colored marshmallows did he or she pick?
2. What did the marshmallows and the cloth represent in your investigation? What effect did the color of the cloth have?
3. When an organism blends into its environment, the organism is *camouflaged*. How does this activity model camouflaged organisms in the wild? What are some weaknesses of this model?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 1

Change over Time

If someone asked you to describe a frog, you might say that a frog has long hind legs, has bulging eyes, and croaks. But what color skin would you say that a frog has?

Once you start to think about frogs, you realize that frogs differ in many ways. These differences set one kind of frog apart from another. The frogs in **Figures 1, 2,** and **3** look different from each other, yet they may live in the same areas.

READING WARM-UP

Objectives

- Identify two kinds of evidence that show that organisms have evolved.
- Describe one pathway through which a modern whale could have evolved from an ancient mammal.
- Explain how comparing organisms can provide evidence that they have ancestors in common.

Terms to Learn

adaptation
species
evolution
fossil
fossil record

READING STRATEGY

Paired Summarizing Read this section silently. In pairs, take turns summarizing the material. Stop to discuss ideas that seem confusing.

Differences Among Organisms

As you can see, each frog has a different characteristic that might help the frog survive. A characteristic that helps an organism survive and reproduce in its environment is called an **adaptation.** Adaptations may be physical, such as a long neck or striped fur. Or adaptations may be behaviors that help an organism find food, protect itself, or reproduce.

Living things that have the same characteristics may be members of the same species. A **species** is a group of organisms that can mate with one another to produce fertile offspring. For example, all strawberry poison arrow frogs are members of the same species and can mate with each other to produce more strawberry poison arrow frogs. Groups of individuals of the same species living in the same place make up a *population*.

Reading Check **How can you tell that organisms are members of the same species?** (*See the Appendix for answers to Reading Checks.*)

Figure 1 The red-eyed tree frog hides among a tree's leaves during the day and comes out at night.

Figure 2 The bright coloring of the strawberry poison arrow frog warns predators that the frog is poisonous.

Figure 3 The smoky jungle frog blends into the forest floor.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Do Species Change over Time?

In a single square mile of rain forest, there may be dozens of species of frogs. Across the Earth, there are millions of different species of organisms. The species that live on Earth today range from single-celled bacteria, which lack cell nuclei, to multicellular fungi, plants, and animals. Have these species always existed on Earth?

Scientists think that Earth has changed a great deal during its history, and that living things have changed, too. Scientists estimate that the planet is 4.6 billion years old. Since life first appeared on Earth, many species have died out, and many new species have appeared. **Figure 4** shows some of the species that have existed during Earth's history.

Scientists observe that species have changed over time. They also observe that the inherited characteristics in populations change over time. Scientists think that as populations change over time, new species form. Thus, newer species descend from older species. The process in which populations gradually change over time is called **evolution.** Scientists continue to develop theories to explain exactly how evolution happens.

adaptation a characteristic that improves an individual's ability to survive and reproduce in a particular environment

species a group of organisms that are closely related and can mate to produce fertile offspring

evolution the process in which inherited characteristics within a population change over generations such that new species sometimes arise

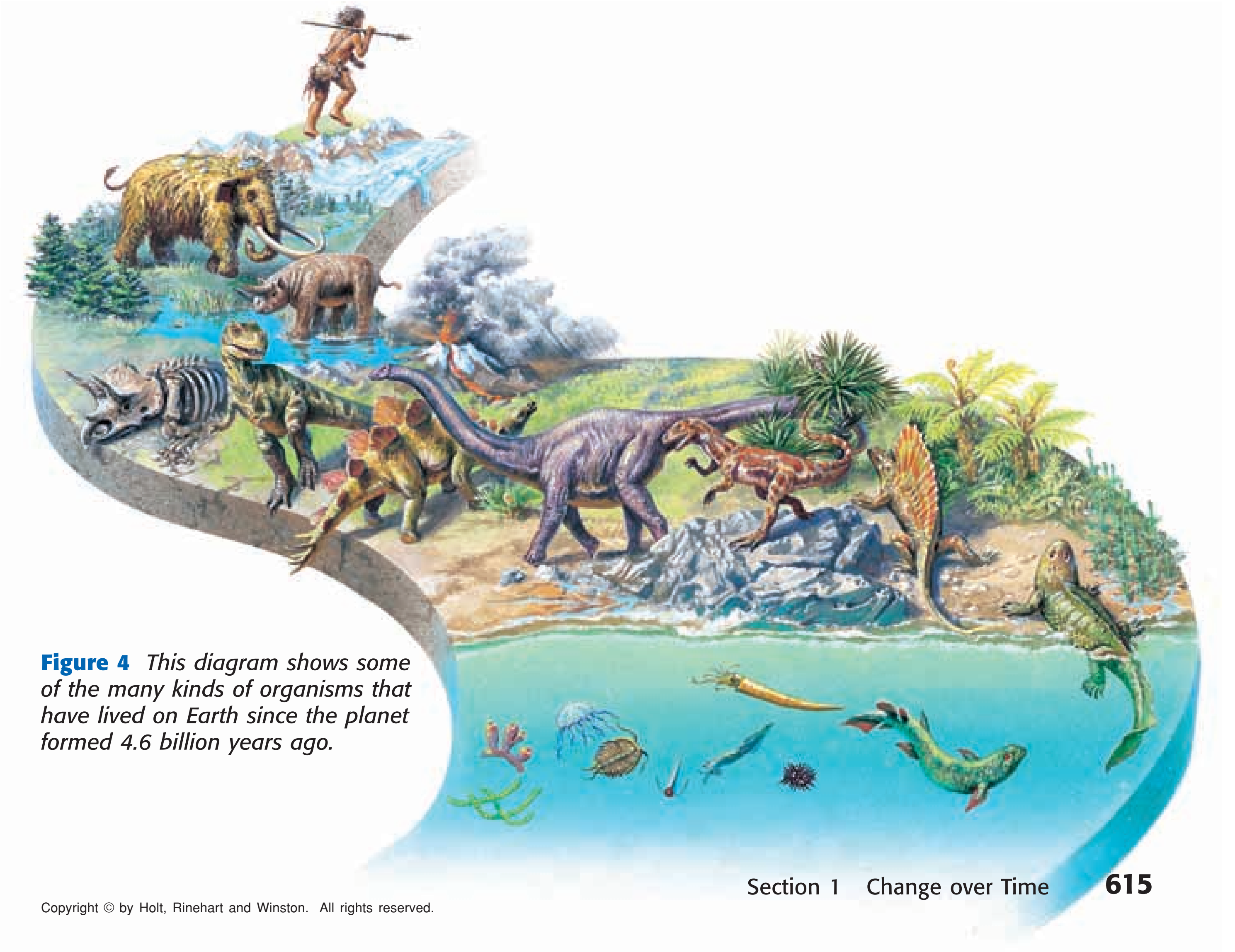


Figure 4 *This diagram shows some of the many kinds of organisms that have lived on Earth since the planet formed 4.6 billion years ago.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

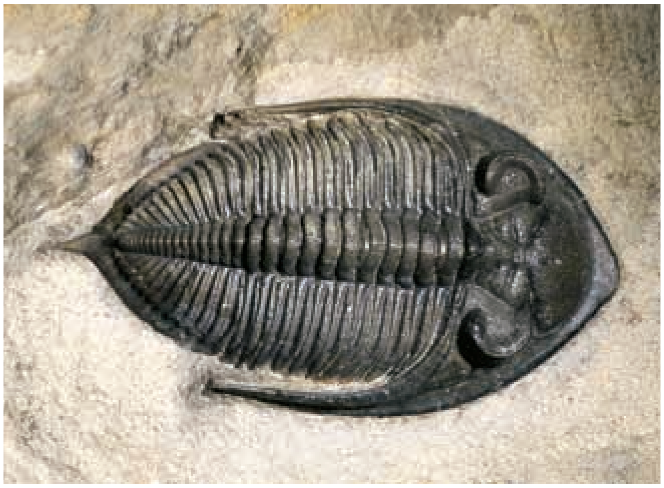


Figure 5 *The fossil on the left is of a trilobite, an ancient aquatic animal. The fossils on the right are of seed ferns.*

Evidence of Changes over Time

Evidence that evolution has happened is buried within Earth. Earth's crust is arranged in layers. These layers are made up of different kinds of rock and soil stacked on top of each other. These layers form when *sediments*, particles of sand, dust, or soil, are carried by wind and water and are deposited in an orderly fashion. Older layers are deposited before newer layers and are buried deeper within Earth.

Fossils

fossil the remains or physical evidence of an organism preserved by geological processes

fossil record a historical sequence of life indicated by fossils found in layers of the Earth's crust

Sometimes, the remains or imprints of once-living organisms are found in the layers of rock. These remains are called **fossils.** Examples of fossils are shown in **Figure 5.** Fossils can be complete organisms, parts of organisms, or just a set of footprints. Fossils usually form when a dead organism is covered by a layer of sediment. Over time, more sediment settles on top of the organism. Minerals in the sediment may seep into the organism and gradually replace the organism with stone. If the organism rots away completely after being covered, it may leave an imprint of itself in the rock.

The Fossil Record

By studying fossils, scientists have made a timeline of life that is known as the **fossil record.** The fossil record organizes fossils by their estimated ages and physical similarities. Fossils found in newer layers of Earth's crust tend to be similar to present-day organisms. This similarity indicates that the fossilized organisms were close relatives of present-day organisms. Fossils from older layers are less similar to present-day organisms than fossils from newer layers are. The older fossils are of earlier life-forms, which may not exist anymore.

✓ *Reading Check* **How does the fossil record organize fossils?**

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Evidence of Ancestry

The fossil record provides evidence about the order in which species have existed. Scientists observe that all living organisms have characteristics in common and inherit characteristics in similar ways. So, scientists think that all living species descended from common ancestors. Evidence of common ancestors can be found in fossils and in living organisms.

Drawing Connections

Scientists examine the fossil record to figure out the relationships between extinct and living organisms. They draw models, such as the one shown in **Figure 6,** that illustrate their hypotheses. The short horizontal line at the top left in the diagram represents a species that lived in the past. Each branch in the diagram represents a group of organisms that descended from that species.

As shown in **Figure 6,** scientists think that whales and some types of hoofed mammals have a common ancestor. This ancestor was probably a mammal that lived on land between 50 million and 70 million years ago. During this time period, the dinosaurs died out and a variety of mammals appeared in the fossil record. The first ocean-dwelling mammals appeared about 50 million years ago. Scientists think that all mammal species alive today evolved from common ancestors.

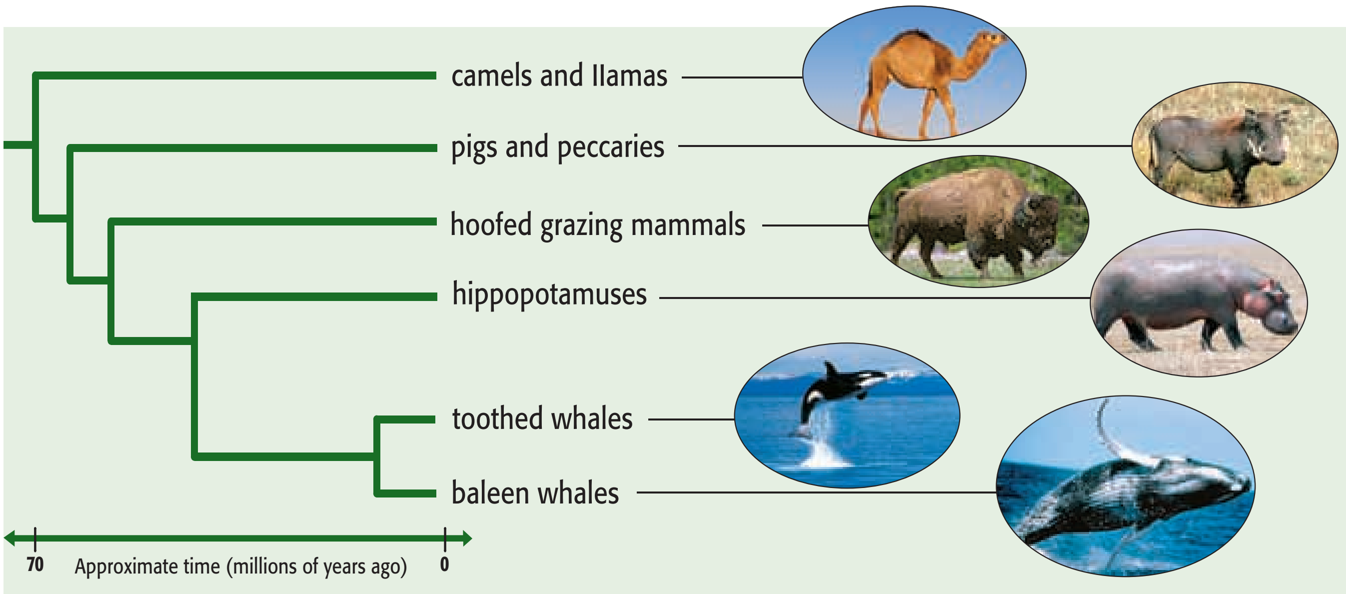
Scientists have named and described hundreds of thousands of living and ancient species. Scientists use information about these species to sketch out a "tree of life" that includes all known organisms. But scientists know that their information is incomplete. For example, parts of Earth's history lack a fossil record. In fact, fossils are rare because specific conditions are necessary for fossils to form.

CONNECTION TO Geology

Sedimentary Rock Fossils are most often found in sedimentary rock. *Sedimentary rock* usually forms when rock is broken into sediment by wind, water, and other means. The wind and water move the sediment around and deposit it. Over time, layers of sediment pile up. Lower layers are compressed and changed into rock. Find out if your area has any sedimentary rocks that contain fossils. Mark the location of such rocks on a copy of a local map.

ACTIVITY

Figure 6 *This diagram is a model of the proposed relationships between ancient and modern mammals that have characteristics similar to whales.*



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Examining Organisms

Examining an organism carefully can give scientists clues about its ancestors. For example, whales seem similar to fish. But unlike fish, whales breathe air, give birth to live young, and produce milk. These traits show that whales are *mammals*. Thus, scientists think that whales evolved from ancient mammals.

Case Study: Evolution of the Whale

Scientists think that the ancient ancestor of whales was probably a mammal that lived on land and that could run on four legs. A more recent ancestor was probably a mammal that spent time both on land and in water. Comparisons of modern whales and a large number of fossils have supported this hypothesis. **Figure 7** illustrates some of this evidence.

Reading Check **What kind of organism do scientists think was an ancient ancestor of whales?**

Figure 7 **Evidence of Whale Evolution**

a ***Pakicetus*** (PAK uh SEE tuhs)
Scientists think that whales evolved from land-dwelling mammals that could run on four legs. One of these ancestors may have been *Pakicetus,* which lived about 50 million years ago. The fossil skeleton and an artist's illustration of *Pakicetus* are shown here. *Pakicetus* was about the size of a wolf.

b ***Ambulocetus*** (AM byoo loh SEE tuhs)
This mammal lived in coastal waters about 49 million years ago. It could swim by kicking its legs and using its tail for balance. It could also waddle on land by using its short legs. *Ambulocetus* was about the size of a dolphin.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Walking Whales

The organisms in **Figure 7** form a sequence between ancient four-legged mammals and modern whales. Several pieces of evidence indicate that these species are related by ancestry. Each species shared some traits with an earlier species. However, some species had new traits that were shared with later species. Yet, each species had traits that allowed it to survive in a particular time and place in Earth's history.

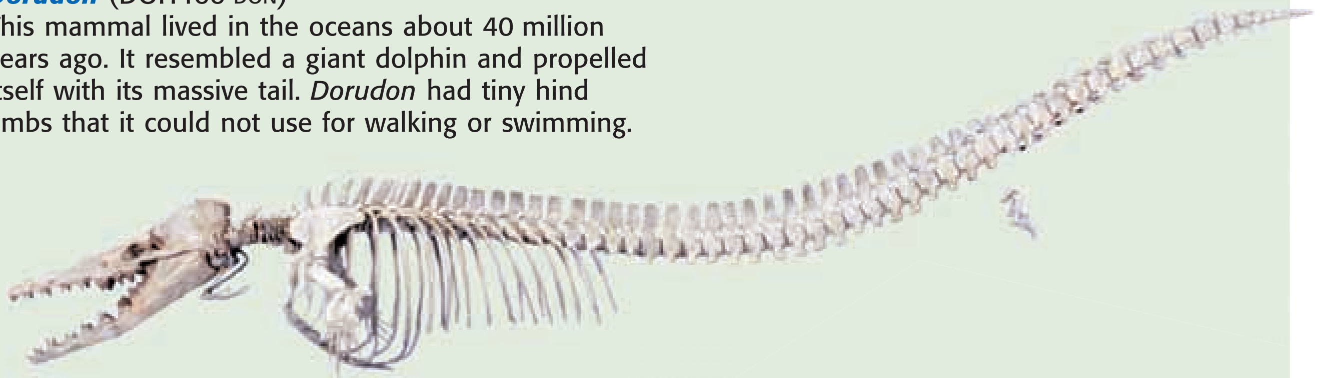
Further evidence can be found inside the bodies of living whales. For example, although modern whales do not have hind limbs, inside their bodies are tiny hip bones, as shown in **Figure 7.** Scientists think that these hip bones were inherited from the whales' four-legged ancestors. Scientists often look at this kind of evidence when they want to determine the relationships between organisms.

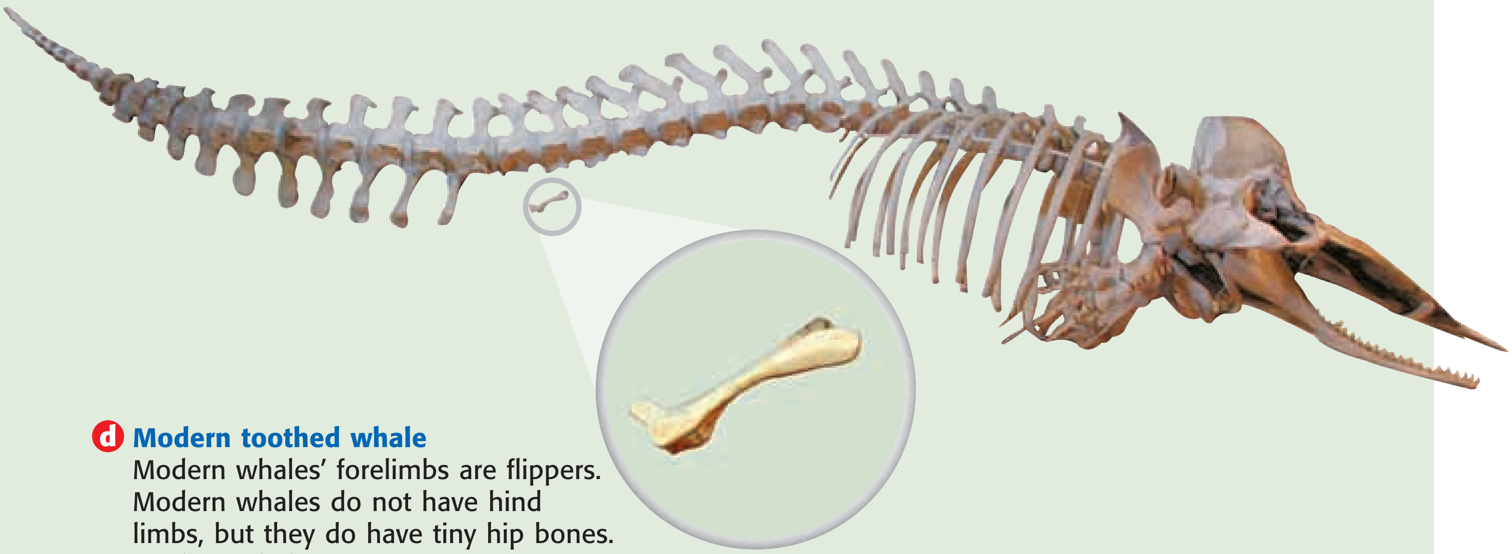
MATH PRACTICE

The Weight of Whales

Whales are the largest animals ever known on Earth. One reason whales can grow so large is that they live in water, which supports their weight in a way that their bones could not. The blue whale—the largest type of whale in existence—is about 24 m long and has a mass of about 99,800 kg. Convert these measurements into feet and pounds, and round to whole numbers.

c ***Dorudon*** (DOH roo DON)
This mammal lived in the oceans about 40 million years ago. It resembled a giant dolphin and propelled itself with its massive tail. *Dorudon* had tiny hind limbs that it could not use for walking or swimming.





d **Modern toothed whale**
Modern whales' forelimbs are flippers. Modern whales do not have hind limbs, but they do have tiny hip bones. Modern whales range in size from 1.4 m porpoises to 33 m blue whales.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

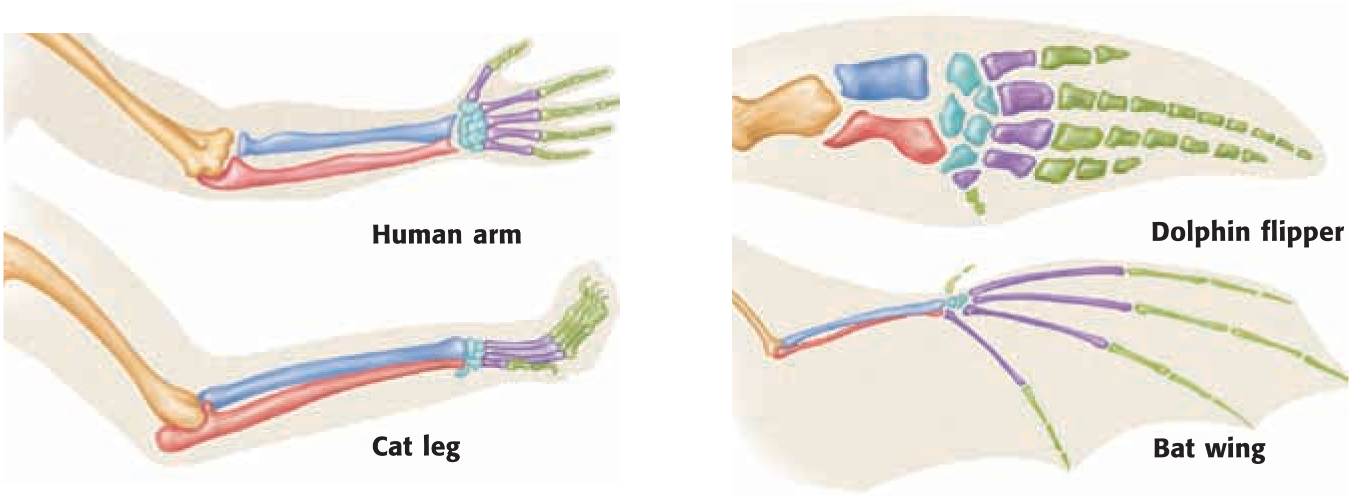


Figure 8 *The bones in the front limbs of these animals are similar. Similar bones are shown in the same color. These limbs are different sizes in life.*

Comparing Organisms

Evidence that groups of organisms have common ancestry can be found by comparing the groups' DNA. Because every organism inherits DNA, every organism inherits the traits determined by DNA. Organisms contain evidence that populations and species undergo changes in traits and DNA over time.

Comparing Skeletal Structures

What does your arm have in common with the front leg of a cat, the front flipper of a dolphin, or the wing of a bat? You might notice that these structures do not look alike and are not used in the same way. But under the surface, there are similarities. Look at **Figure 8.** The structure and order of bones of a human arm are similar to those of the front limbs of a cat, a dolphin, and a bat.

These similarities suggest that cats, dolphins, bats, and humans had a common ancestor. Over millions of years, changes occurred in the limb bones of the ancestor's descendants. Eventually, the bones performed different functions in each type of animal.

Comparing DNA

Interestingly, the DNA of a house cat is similar to the DNA of a tiger. Scientists have learned that traits are inherited through DNA's genetic code. So, scientists can test the following hypothesis: If species that have similar traits evolved from a common ancestor, the species will have similar genetic information. In fact, scientists find that species that have many traits in common do have similarities in their DNA. For example, the DNA of house cats is more similar to the DNA of tigers than to the DNA of dogs. The fact that all existing species have DNA supports the theory that all species share a common ancestor.

Reading Check **If two species have similar DNA, what hypothesis is supported?**

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION Review

Summary

- Evolution is the process in which inherited characteristics within a population change over generations, sometimes giving rise to new species. Scientists continue to develop theories to explain how evolution happens.
- Evidence that organisms evolve can be found by comparing living organisms to each other and to the fossil record. Such comparisons provide evidence of common ancestry.
- Scientists think that modern whales evolved from an ancient, land-dwelling mammal ancestor. Fossil organisms that support this hypothesis have been found.
- Evidence of common ancestry among living organisms is provided by comparing DNA and inherited traits. Species that have a common ancestor will have traits and DNA that are more similar to each other than to those of distantly related species.

Using Key Terms

Complete each of the following sentences by choosing the correct term from the word bank.

adaptation	species
fossil	evolution

1. Members of the same ___ can mate with one another to produce offspring.
2. A(n) ___ helps an organism survive.
3. When populations change over time, ___ has occurred.

Understanding Key Ideas

4. A human's arm, a cat's front leg, a dolphin's front flipper, and a bat's wing
   - **a.** have similar kinds of bones.
   - **b.** are used in similar ways.
   - **c.** are very similar to insect wings and jellyfish tentacles.
   - **d.** have nothing in common.
5. How does the fossil record show that species have changed over time?
6. What evidence do fossils provide about the ancestors of whales?

Critical Thinking

7. **Making Comparisons** Other than the examples provided in the text, how are whales different from fishes?
8. **Forming Hypotheses** Is a person's DNA likely to be more similar to the DNA of his or her biological parents or to the DNA of one of his or her cousins? Explain your answer.

Interpreting Graphics

9. The photograph below shows the layers of sedimentary rock exposed during the construction of a road. Imagine that a species that lived 200 million years ago is found in layer **b.** Would the species' ancestor, which lived 250 million years ago, most likely be found in layer **a** or in layer **c**? Explain your answer.

SCILINKS®
NSTA
Developed and maintained by the National Science Teachers Association
For a variety of links related to this chapter, go to www.scilinks.org
Topic: Species and Adaptation; Fossil Record
SciLinks code: HSM1433; HSM0615

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 2

How Does Evolution Happen?

READING WARM-UP

Objectives

- List four sources of Charles Darwin's ideas about evolution.
- Describe the four parts of Darwin's theory of evolution by natural selection.
- Relate genetics to evolution.

Terms to Learn

trait
selective breeding
natural selection

READING STRATEGY

Brainstorming The key idea of this section is natural selection. Brainstorm words and phrases related to natural selection.

Imagine that you are a scientist in the 1800s. Fossils of some very strange animals have been found. And some familiar fossils have been found where you would least expect them. How did seashells end up on the tops of mountains?

In the 1800s, geologists began to realize that the Earth is much older than anyone had previously thought. Evidence showed that gradual processes had changed the Earth's surface over millions of years. Some scientists saw evidence of evolution in the fossil record. However, no one had been able to explain *how* evolution happens—until Charles Darwin.

Charles Darwin

In 1831, 21-year-old Charles Darwin, shown in **Figure 1,** graduated from college. Like many young people just out of college, Darwin didn't know what he wanted to do with his life. His father wanted him to become a doctor, but seeing blood made Darwin sick. Although he eventually earned a degree in theology, Darwin was most interested in the study of plants and animals.

So, Darwin signed on for a five-year voyage around the world. He served as the *naturalist*—a scientist who studies nature—on the British ship the HMS *Beagle,* similar to the ship in **Figure 2.** During the trip, Darwin made observations that helped him form a theory about how evolution happens.

Figure 1 *Charles Darwin wanted to understand the natural world.*

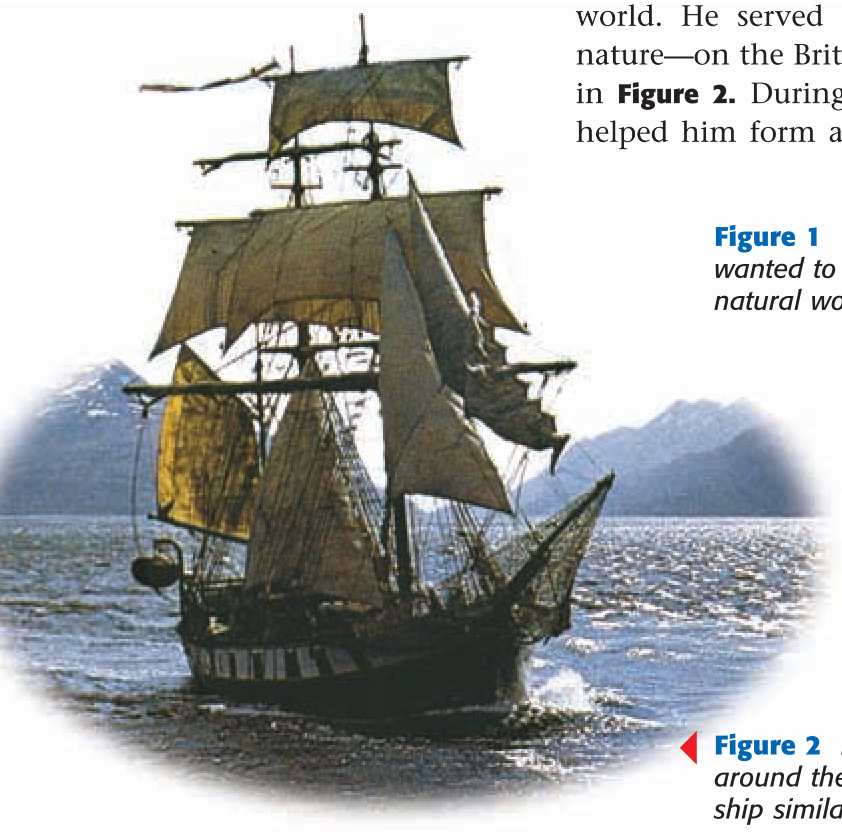


Figure 2 *Darwin sailed around the world on a ship similar to this one.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 3 *The course of the HMS* Beagle *is shown by the red line. The journey began and ended in England.*

Darwin's Excellent Adventure

The *Beagle*'s journey is charted in **Figure 3.** Along the way, Darwin collected thousands of plant and animal samples. He kept careful notes of his observations. One interesting place that the ship visited was the Galápagos Islands. These islands are found 965 km (600 mi) west of Ecuador, a country in South America.

Reading Check **Where are the Galápagos Islands?** (*See the Appendix for answers to Reading Checks.*)

Darwin's Finches

Darwin noticed that the animals and plants on the Galápagos Islands were a lot like those in Ecuador. However, they were not exactly the same. The finches of the Galápagos Islands, for example, were a little different from the finches in Ecuador. And the finches on each island differed from the finches on the other islands. As **Figure 4** shows, the beak of each finch is adapted to the way the bird usually gets food.

Figure 4 **Some Finches of the Galápagos Islands**

The **large ground finch** has a wide, strong beak that it uses to crack open big, hard seeds. This beak works like a nutcracker.

The **cactus finch** has a tough beak that it uses for eating cactus parts and insects. This beak works like a pair of needle-nose pliers.

The **warbler finch** has a small, narrow beak that it uses to catch small insects. This beak works like a pair of tweezers.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Darwin's Thinking

After returning to England, Darwin puzzled over the animals of the Galápagos Islands. He tried to explain why the animals seemed so similar to each other yet had so many different adaptations. For example, Darwin hypothesized that the island finches were descended from South American finches. The first finches on the islands may have been blown from South America by a storm. Over many generations, the finches may have adapted to different ways of life on the islands.

During the course of his travels, Darwin came up with many new ideas. Before sharing these ideas, he spent several years analyzing his evidence. He also gathered ideas from many other people.

Ideas About Breeding

trait a genetically determined characteristic

selective breeding the human practice of breeding animals or plants that have certain desired characteristics

In Darwin's time, farmers and breeders had produced many kinds of farm animals and plants. These plants and animals had traits that were desired by the farmers and breeders. **Traits** are specific characteristics that can be passed from parent to offspring through genes. The process in which humans select which plants or animals to reproduce based on certain desired traits is called **selective breeding.** Most pets, such as the dogs in **Figure 5,** have been bred for various desired traits.

You can see the results of selective breeding in many kinds of organisms. For example, people have bred horses that are particularly fast or strong. And farmers have bred crops that produce large fruit or that grow in specific climates.

Figure 5 *Over the past 12,000 years, dogs have been selectively bred to produce more than 150 breeds.*

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Quick Lab

Population Growth Versus Food Supply

1. Get an **egg carton** and a **bag of rice.** Use a **marker** to label one row of the carton "Food supply." Then, label the second row "Human population."
2. In the row labeled "Food supply," place one grain of rice in the first cup. Place two grains of rice in the second cup, and place three grains of rice in the third cup. In each subsequent cup, place one more grain than you placed in the previous cup. Imagine that each grain represents enough food for one person's lifetime.
3. In the row labeled "Human population," place one grain of rice in the first cup. Place two grains in the second cup, and place four grains in the third cup. In each subsequent cup, place twice as many grains as you placed in the previous cup. This rice represents people.
4. How many units of food are in the sixth cup? How many "people" are in the sixth cup? If this pattern continued, what would happen?
5. Describe how the patterns in the food supply and in the human population differ. Explain how the patterns relate to Malthus's hypothesis.

Ideas About Population

During Darwin's time, Thomas Malthus wrote a famous book entitled *An Essay on the Principle of Population*. Malthus noted that humans have the potential to reproduce rapidly. He warned that food supplies could not support unlimited population growth. **Figure 6** illustrates this relationship. However, Malthus pointed out that human populations are limited by choices that humans make or by problems such as starvation and disease.

After reading Malthus's work, Darwin realized that any species can produce many offspring. He also knew that the populations of all species are limited by starvation, disease, competition, and predation. Only a limited number of individuals survive to reproduce. Thus, there is something special about the survivors. Darwin reasoned that the offspring of the survivors inherit traits that help the offspring survive in their environment.

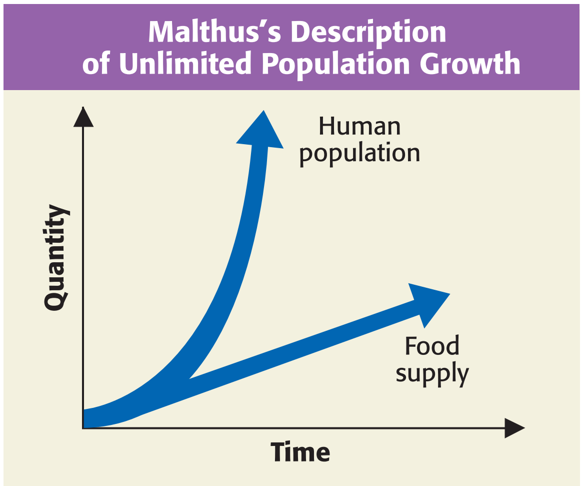


Figure 6 *Malthus thought that the human population could increase more quickly than the food supply, with the result that there would not be enough food for everyone.*

Ideas About Earth's History

Darwin had begun to think that species could evolve over time. But most geologists at the time did not think that Earth was old enough to allow for slow changes. Darwin learned new ideas from *Principles of Geology,* a book by Charles Lyell. This book presented evidence that Earth had formed by natural processes over a long period of time. It became clear to Darwin that Earth was much older than anyone had imagined.

Reading Check **What did Darwin learn from Charles Lyell?**

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Darwin's Theory of Natural Selection

After he returned from his voyage on the HMS *Beagle*, Darwin privately struggled with his ideas for about 20 years. Then, in 1858, Darwin received a letter from a fellow naturalist named Alfred Russel Wallace. Wallace had arrived at the same ideas about evolution that Darwin had. Darwin grew more and more motivated to present his ideas. In 1859, Darwin published a famous book called *On the Origin of Species by Means of Natural Selection*. In his book, Darwin proposed the theory that evolution happens through a process that he called **natural selection.** This process, explained in **Figure 7,** has four parts.

natural selection the process by which individuals that are better adapted to their environment survive and reproduce more successfully than less well adapted individuals do; a theory to explain the mechanism of evolution

Reading Check **What is the title of Darwin's famous book?**

Figure 7 **Four Parts of Natural Selection**

1 Overproduction A tarantula's egg sac may hold 500–1,000 eggs. Some of the eggs will survive and develop into adult spiders. Some will not.

2 Inherited Variation Every individual has its own combination of traits. Each tarantula is similar to, but not identical to, its parents.

3 Struggle to Survive Some tarantulas may be caught by predators, such as this wasp. Other tarantulas may starve or get a disease. Only some of the tarantulas will survive to adulthood.

4 Successful Reproduction The tarantulas that are best adapted to their environment are likely to have many offspring that survive.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Genetics and Evolution

Darwin lacked evidence for parts of his theory. For example, he knew that organisms inherit traits, but not *how* they inherit traits. He knew that there is great variation among organisms, but not *how* that variation occurs. Today, scientists have found most of the evidence that Darwin lacked. They know that variation happens as a result of differences in genes. Changes in genes may happen whenever organisms produce offspring. Some genes make an organism more likely to survive to reproduce. The process called *selection* happens when only organisms that carry these genes can survive to reproduce. New fossil discoveries and new information about genes add to scientists' understanding of natural selection and evolution.

SECTION Review

Summary

- Darwin explained that evolution occurs through natural selection. His theory has four parts:
  1. Each species produces more offspring than will survive to reproduce.
  2. Individuals within a population have slightly different traits.
  3. Individuals within a population compete with each other for limited resources.
  4. Individuals that are better equipped to live in an environment are more likely to survive to reproduce.
- Modern genetics helps explain the theory of natural selection.

Using Key Terms

1. In your own words, write a definition for the term *trait*.
2. Use the following terms in the same sentence: *selective breeding* and *natural selection*.

Understanding Key Ideas

3. Modern scientific explanations of evolution
   a. have replaced Darwin's theory.
   b. rely on genetics instead of natural selection.
   c. fail to explain how traits are inherited.
   d. combine the principles of natural selection and genetic inheritance.
4. Describe the observations that Darwin made about the species on the Galápagos Islands.
5. Summarize the ideas that Darwin developed from books by Malthus and Lyell.
6. Describe the four parts of Darwin's theory of evolution by natural selection.
7. What knowledge did Darwin lack that modern scientists now use to explain evolution?

Math Skills

8. In a sample of 80 beetles, 50 beetles had 4 spots each, and the rest had 6 spots each. What was the average number of spots per beetle?

Critical Thinking

9. **Making Comparisons** In selective breeding, humans influence the course of evolution. What determines the course of evolution in natural selection?
10. **Predicting Consequences** Suppose that an island in the Pacific Ocean was just formed by a volcano. Over the next million years, how might species evolve on this island?

SCILINKS®
NSTA
Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Galápagos Islands; Darwin and Natural Selection

SciLinks code: HSM0631; HSM0378

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SECTION 3

Natural Selection in Action

Have you ever had to take an antibiotic? Antibiotics are supposed to kill bacteria. But sometimes, bacteria are not killed by the medicine. Do you know why?

READING WARM-UP

Objectives

- Give three examples of natural selection in action.
- Outline the process of speciation.

Terms to Learn

generation time
speciation

READING STRATEGY

Prediction Guide Before reading this section, write the title of each heading in this section. Next, under each heading, write what you think you will learn.

A population of bacteria might develop an adaptation through natural selection. Most bacteria are killed by the chemicals in antibiotics. But in some cases, a few bacteria are naturally *resistant* to the chemicals, so they are not killed. These survivors are then able to pass this adaptation to their offspring. This situation is an example of how natural selection works.

Changes in Populations

The theory of natural selection explains how a population changes in response to its environment. If natural selection is always taking place, a population will tend to be well adapted to its environment. But not all individuals are the same. The individuals that are likely to survive and reproduce are those that are best adapted at the time.

Adaptation to Hunting

Changes in populations are sometimes observed when a new force affects the survival of individuals. In Uganda, scientists think that hunting is affecting the elephant population. In 1930, about 99% of the male elephants in one area had tusks. Only 1% of the elephants were born without tusks. Today, as few as 85% of the male elephants in that area have tusks. What happened?

A male African elephant that has tusks is shown in **Figure 1.** The ivory of an elephant's tusks is very valuable. People hunt the elephants for their tusks. As a result, fewer of the elephants that have tusks survive to reproduce, and more of the tuskless elephants survive. When the tuskless elephants reproduce, they pass the tuskless trait to their offspring.

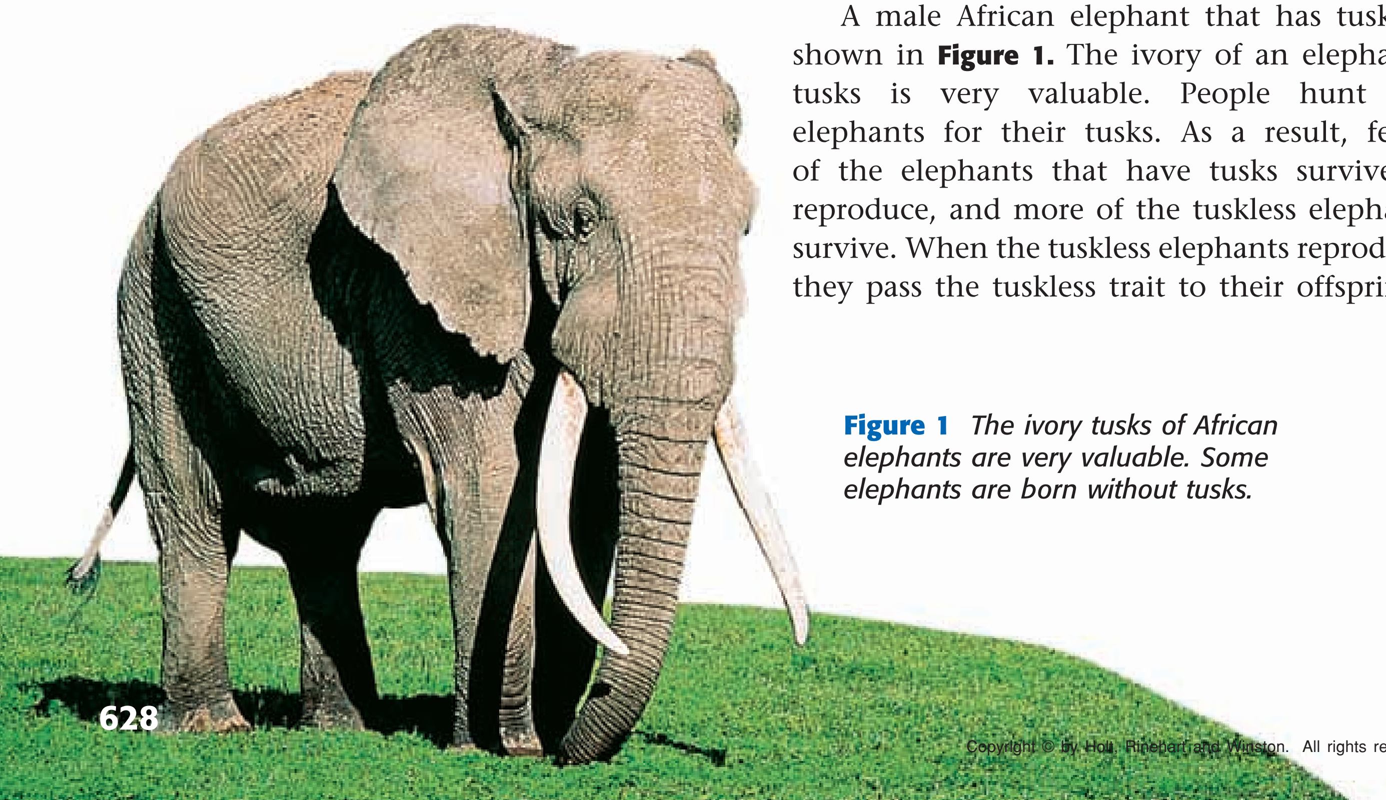


Figure 1 *The ivory tusks of African elephants are very valuable. Some elephants are born without tusks.*

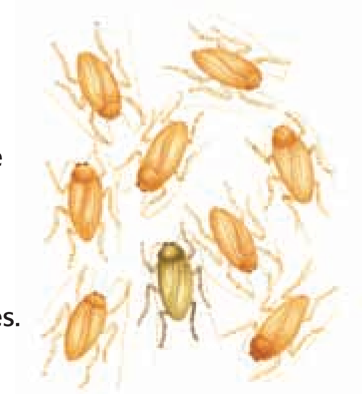
Copyright © by Holt, Rinehart and Winston. All rights reserved.

Figure 2 **Natural Selection of Insecticide Resistance**

1 An insecticide will kill most insects, but a few may survive. These survivors have genes that make them resistant to the insecticide.

2 The survivors then reproduce, passing the insecticide-resistance genes to their offspring.

3 In time, the replacement population of insects is made up mostly of individuals that have the insecticide-resistance genes.



4 When the same kind of insecticide is used on the insects, only a few are killed because most of them are resistant to that insecticide.

Insecticide Resistance

People have always wanted to control the insect populations around their homes and farms. Many insecticides are used to kill insects. But some chemicals that used to work well do not work as well anymore. Some individual insects within the population are resistant to certain insecticides. **Figure 2** shows how a population of insects might become resistant to common insecticides.

More than 500 kinds of insects are now resistant to certain insecticides. Insects can quickly develop resistance because they often produce many offspring and have short generation times. **Generation time** is the average time between one generation of offspring and the next.

generation time the period between the birth of one generation and the birth of the next generation

Reading Check **Why do insects quickly develop resistance to insecticides?** (*See the Appendix for answers to Reading Checks.*)

Competition for Mates

In the process of evolution, survival is simply not enough. Natural selection is at work when individuals reproduce. In organisms that reproduce sexually, finding a mate is part of the struggle to reproduce. Many species have so much competition for mates that interesting adaptations result. For example, the females of many bird species prefer to mate with males that have certain types of colorful feathers.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Forming a New Species

Sometimes, drastic changes that can form a new species take place. In the animal kingdom, a *species* is a group of organisms that can mate with each other to produce fertile offspring. A new species may form after a group becomes separated from the original population. This group forms a new population. Over time, the two populations adapt to their different environments. Eventually, the populations can become so different that they can't mate anymore. Each population may then be considered a new species. The formation of a new species as a result of evolution is called **speciation** (SPEE shee AY shuhn). **Figure 3** shows how new species of Galápagos finches may have formed. Speciation may happen in other ways as well.

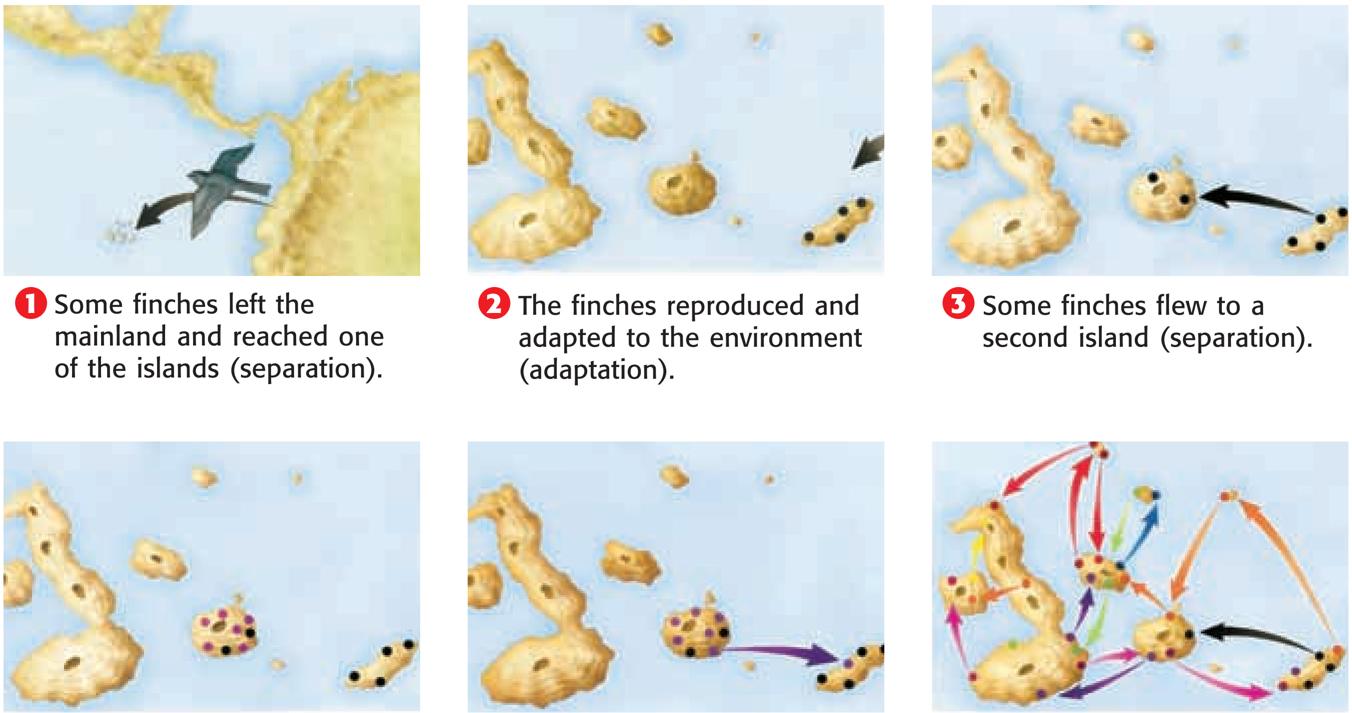
speciation the formation of new species as a result of evolution

Separation

Speciation often begins when a part of a population becomes separated from the rest. The process of separation can happen in several ways. For example, a newly formed canyon, mountain range, or lake can divide the members of a population.

Reading Check **How can parts of a population become separated?**

Figure 3 **The Evolution of Galápagos Finch Species**



1 Some finches left the mainland and reached one of the islands (separation).

2 The finches reproduced and adapted to the environment (adaptation).

3 Some finches flew to a second island (separation).

4 The finches reproduced and adapted to the different environment (adaptation).

5 Some finches flew back to the first island but could no longer interbreed with the finches there (division).

6 This process may have occurred over and over again as the finches flew to the other islands.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Adaptation

Populations constantly undergo natural selection. After two groups have separated, natural selection may act on each group in different ways. Over many generations, the separated groups may evolve different sets of traits. If the environmental conditions for each group differ, the adaptations in the groups will also differ.

Division

Over many generations, two separated groups of a population may become very different. Even if a geographical barrier is removed, the groups may not be able to interbreed anymore. At this point, the two groups are no longer the same species.

Figure 4 shows another way that populations may stop interbreeding. Leopard frogs and pickerel frogs probably had the same ancestor species. Then, at some point, some of these frogs began to mate at different times during the year.

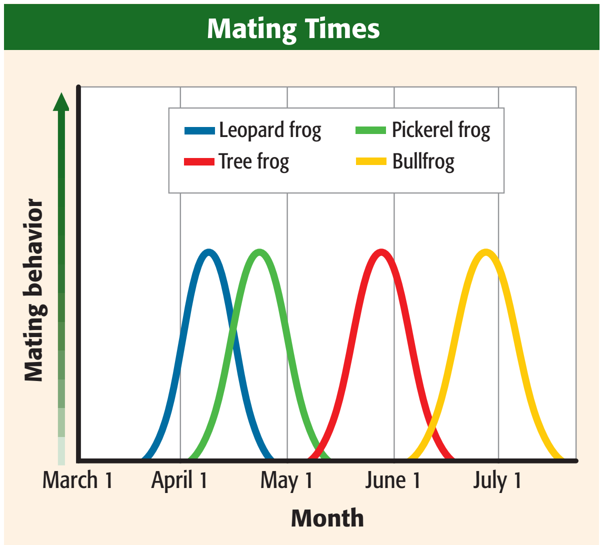


Figure 4 *The leopard frog and the pickerel frog are similar species. However, leopard frogs do not search for mates at the same time of year that pickerel frogs do.*

SECTION Review

Summary

- Natural selection explains how populations adapt to changes in their environment. A variety of examples of such adaptations can be found.
- Natural selection also explains how one species may evolve into another. Speciation occurs as populations undergo separation, adaptation, and division.

Using Key Terms

1. In your own words, write a definition for the term *speciation*.

Understanding Key Ideas

2. Two populations have evolved into two species when
   - **a.** the populations are separated.
   - **b.** the populations look different.
   - **c.** the populations can no longer interbreed.
   - **d.** the populations adapt.
3. Explain why the number of tuskless elephants in Uganda may be increasing.

Math Skills

4. A female cockroach can produce 80 offspring at a time. If half of the offspring produced by a certain female are female and each female produces 80 offspring, how many cockroaches are there in the third generation?

Critical Thinking

5. **Forming Hypotheses** Most kinds of cactus have leaves that grow in the form of spines. The stems or trunks become thick, juicy pads or barrels. Explain how these cactus parts might have evolved.
6. **Making Comparisons** Suggest an organism other than an insect that might evolve an adaptation to human activities.

SCILINKS® NSTA Developed and maintained by the National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Species and Adaptation
SciLinks code: HSM1433

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Using Scientific Methods

Inquiry Lab

Survival of the Chocolates

OBJECTIVES

Form a hypothesis about the fate of the candy-coated chocolates.

Predict what will happen to the candy-coated chocolates.

Design and conduct an experiment to test your hypothesis.

MATERIALS

- chocolates, candy-coated, small, in a variety of colors (about 100)
- items to be determined by the students and approved by the teacher

SAFETY

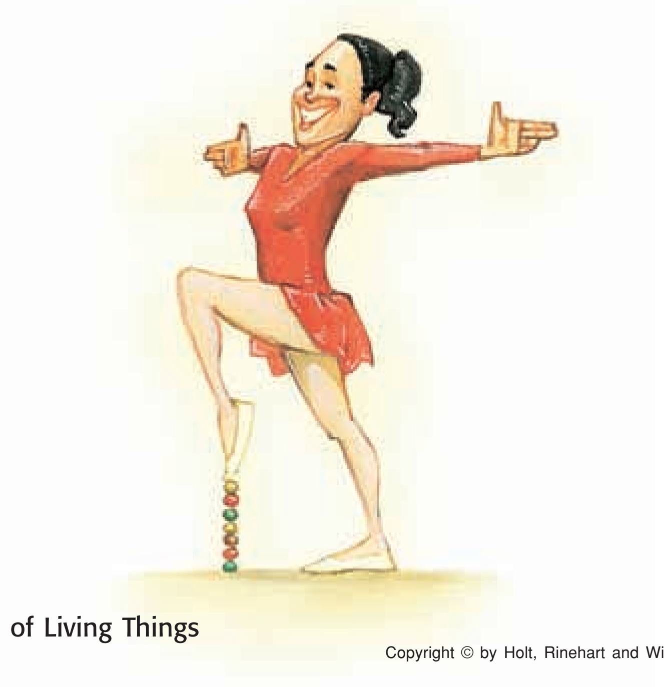
Imagine a world populated with candy, and hold that delicious thought in your head for just a moment. Try to apply the idea of natural selection to a population of candy-coated chocolates. According to the theory of natural selection, individuals who have favorable adaptations are more likely to survive. In the "species" of candy-coated chocolates you will study in this experiment, the characteristics of individual chocolates may help them "survive." For example, shell strength (the strength of the candy coating) could be an adaptive advantage. Plan an experiment to find out which characteristics of the chocolates are favorable "adaptations."

Ask a Question

1. What might "survival" mean for a candy-coated chocolate? What are some ways you can test which chocolates are the "strongest" or "most fit" for their environment? Also, write down any other questions that you could ask about the "survival" of the chocolates.

Form a Hypothesis

2. Form a hypothesis, and make a prediction. For example, if you chose to study candy color, your prediction might be similar to this: If the ___ colored shell is the strongest, then fewer of the chocolates with this color of shell will ___ when ___.



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Test the Hypothesis

3. Design a procedure to determine which type of candy-coated chocolate is most likely to survive. In your plan, be sure to include materials and tools you may need to complete this procedure.
4. Check your experimental design with your teacher before you begin. Your teacher will supply the candy and assist you in gathering materials and tools.
5. Record your results in a data table. Be sure to organize your data in a clear and understandable way.

Analyze the Results

1. **Describing Events** Write a report that describes your experiment. Be sure to include tables and graphs of the data you collected.

Draw Conclusions

2. **Evaluating Data** In your report, explain how your data either support or do not support your hypothesis. Include possible errors and ways to improve your procedure.

Applying Your Data

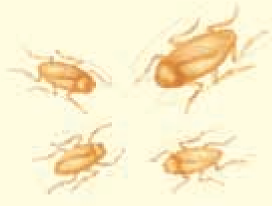
Can you think of another characteristic of the chocolates that can be tested to determine which type is best adapted to survive? Explain your idea, and describe how you might test it.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Chapter Review

USING KEY TERMS

Complete each of the following sentences by choosing the correct term from the word bank.



adaptation
evolution
generation time
species
speciation
fossil record
selective breeding
natural selection

1. When a single population evolves into two populations that cannot interbreed anymore, ___ has occurred.

2. Darwin's theory of ___ explained the process by which organisms become well-adapted to their environment.

3. A group of organisms that can mate with each other to produce offspring is known as a(n) ___.

4. The ___ provides information about organisms that have lived in the past.

5. In ___, humans select organisms with desirable traits that will be passed from one generation to another.

6. A(n) ___ helps an organism survive better in its environment.

7. Populations of insects and bacteria can evolve quickly because they usually have a short ___.

UNDERSTANDING KEY IDEAS

Multiple Choice

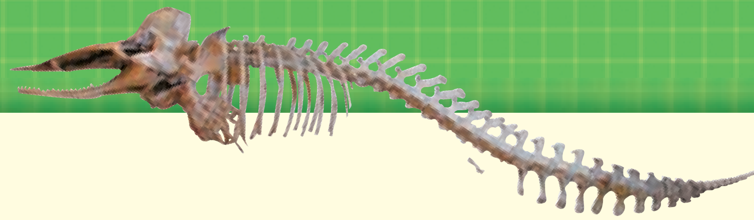
8. Fossils are commonly found in
   a. sedimentary rock.
   b. all kinds of rock.
   c. granite.
   d. loose sand.

9. The fact that all organisms have DNA as their genetic material is evidence that
   a. all organisms undergo natural selection.
   b. all organisms may have descended from a common ancestor.
   c. selective breeding takes place every day.
   d. genetic resistance rarely occurs.

10. Charles Darwin puzzled over differences in the ___ of the different species of Galápagos finches.
   a. webbed feet
   b. beaks
   c. bone structure of the wings
   d. eye color

11. Darwin observed variations among individuals within a population, but he did not realize that these variations were caused by
   a. interbreeding.
   b. differences in food.
   c. differences in genes.
   d. selective breeding.

Copyright © by Holt, Rinehart and Winston. All rights reserved.



Short Answer

12 Identify two ways that organisms can be compared to provide evidence of evolution from a common ancestor.

13 Describe evidence that supports the hypothesis that whales evolved from land-dwelling mammals.

14 Why are some animals more likely to survive to adulthood than other animals are?

15 Explain how genetics is related to evolution.

16 Outline an example of the process of speciation.

CRITICAL THINKING

17 **Concept Mapping** Use the following terms to create a concept map: *struggle to survive*, *theory*, *genetic variation*, *Darwin*, *overpopulation*, *natural selection*, and *successful reproduction*.

18 **Making Inferences** How could natural selection affect the songs that birds sing?

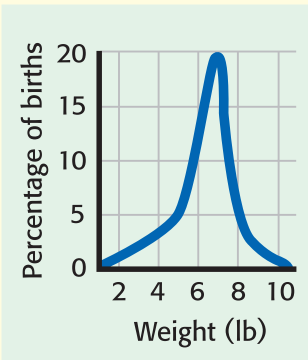
19 **Forming Hypotheses** In Australia, many animals look like mammals from other parts of the world. But most of the mammals in Australia are marsupials, which carry their young in pouches after birth. Few kinds of marsupials are found anywhere else in the world. What is a possible explanation for the presence of so many of these unique mammals in Australia?

20 **Analyzing Relationships** Geologists have evidence that the continents were once a single giant continent. This giant landform eventually split apart, and the individual continents moved to their current positions. What role might this drifting of continents have played in evolution?

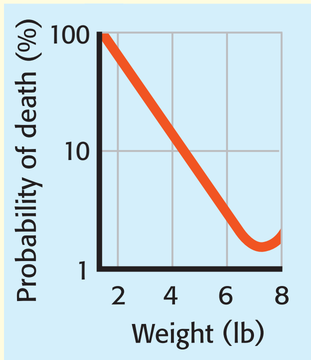
INTERPRETING GRAPHICS

The graphs below show information about the infants that are born and the infants that have died in a population. The weight of each infant was measured at birth. Use the graphs to answer the questions that follow.

Infant Births by Birth Weight



Infant Deaths by Birth Weight

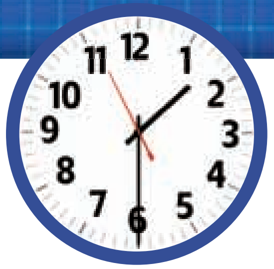


21 What is the most common birth weight?

22 At which birth weight is an infant most likely to survive?

23 How do the principles of natural selection help explain why there are more deaths among babies whose birth weights are low than among babies whose birth weights are average?

Copyright © by Holt, Rinehart and Winston. All rights reserved.



Standardized Test Preparation

EOG Prep

READING

Read each of the passages below. Then, answer the questions that follow each passage.

Passage 1 When the Grand Canyon was forming, a single population of tassel-eared squirrels may have been separated into two groups. Today, descendants of the two groups live on opposite sides of the canyon. The two groups share many characteristics, but they do not look the same. For example, both groups have tasseled ears, but each group has a unique fur color pattern. An important difference between the groups is that the Abert squirrels live on the south rim of the canyon, and the Kaibab squirrels live on the north rim.

The environments on the two sides of the Grand Canyon are different. The north rim is about 370 m higher than the south rim. Almost twice as much precipitation falls on the north rim than on the south rim every year. Over many generations, the two groups of squirrels have adapted to their new environments. Over time, the groups became very different. Many scientists think that the two types of squirrels are no longer the same species. The development of these two squirrel groups is an example of speciation in progress.

1. Which of the following statements **best** describes the main idea of this passage?

A Speciation is evident in two groups of squirrels in the Grand Canyon area.
B Two groups of squirrels in the Grand Canyon area are closely related.
C Two species can form from one species. This process is called *speciation*.
D There are two groups of squirrels because the Grand Canyon has two sides.

2. Which of the following statements about the two types of squirrels is true?

F They look the same.
G They live in similar environments.
H They have tasseled ears.
I They can interbreed with each other.

Passage 2 You know from experience that individuals in a population are not exactly the same. If you look around the room, you will see a lot of differences among your classmates. You may have even noticed that no two dogs or two cats are exactly the same. No two individuals have exactly the same adaptations. For example, one cat may be better at catching mice, and another is better at running away from dogs. Observations such as these form the basis of the theory of natural selection. Because adaptations help organisms survive to reproduce, the individuals that are better adapted to their environment are more likely to pass their traits to future generations.

1. In the passage, what does *population* mean?

A a school
B some cats and dogs
C a group of the same type of organism
D a group of individuals that are the same

2. In this passage, which of the following are given as examples of adaptations?

F differences among classmates
G differences among cats
H differences between cats and dogs
I differences among environments

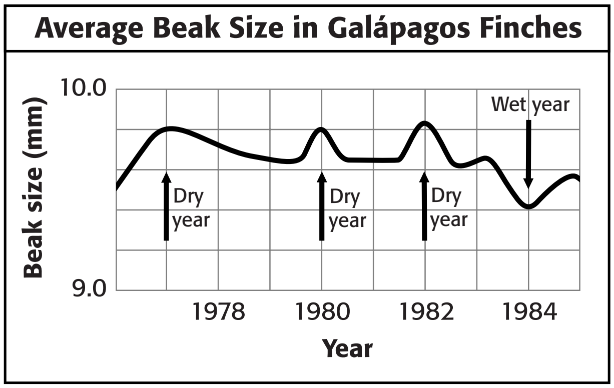
3. Which of the following statements about the individuals in a population that survive to reproduce is true?

A They have the same adaptations.
B They are likely to pass on adaptations to the next generation.
C They form the basis of the theory of natural selection.
D They are always better hunters.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

INTERPRETING GRAPHICS

The graph below shows average beak sizes of a group of finches on one island over several years. Use the graph to answer the questions that follow.



1. In which of the years studied was average beak size the largest?

A 1977
B 1980
C 1982
D 1984

2. If beak size in this group of birds is linked to the amount of rainfall, what can you infer about the year 1976 on this island?

F The year 1976 was drier than 1977.
G The year 1976 was drier than 1980.
H The year 1976 was wetter than 1977.
I The year 1976 was wetter than 1984.

3. During which year(s) was rainfall probably the lowest on the island?

A 1978, 1980, and 1982
B 1977, 1980, 1982, and 1984
C 1982
D 1984

4. Which of the following statements **best** summarizes this data?

F Average beak size stayed about the same except during wet years.
G Average beak size decreased during dry years and increased during wet years.
H Average beak size increased during dry years and decreased during wet years.
I Average beak size changed randomly.

MATH

Read each question below, and choose the best answer.

Average Beak Measurements of Birds of the Colores Islands

Island	Average beak length (mm)	Average beak width (mm)	Number of unique species
Verde	9.7	6.5	5
Azul	8.9	8.7	15
Rosa	5.2	8.0	10

1. What is the ratio of the number of species on Verde Island to the total number of species on all three of the Colores Islands?

A 1:2
B 1:5
C 1:6
D 5:15

2. What percentage of all bird species on the Colores Islands are on Rosa Island?

F approximately 15%
G approximately 30%
H approximately 50%
I approximately 80%

3. On which of the islands is the ratio of average beak length to average beak width closest to 1:1?

A Verde Island
B Azul Island
C Rosa Island
D There is not enough information to determine the answer.

4. On which island does the bird with the smallest beak length live?

F Verde Island
G Azul Island
H Rosa Island
I There is not enough information to determine the answer.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Science in Action

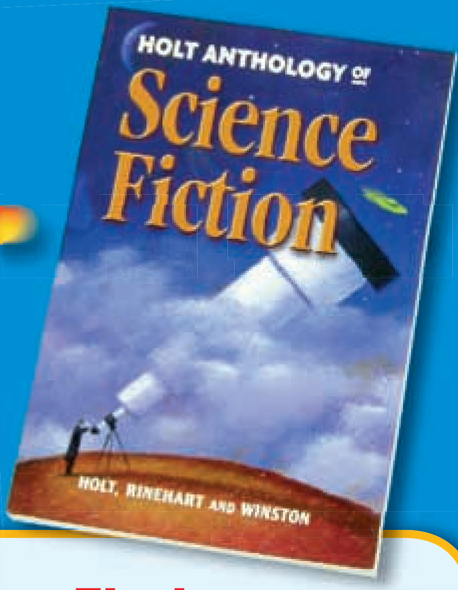
Science, Technology, and Society

Seed Banks

All over the world, scientists are making deposits in a special kind of bank. These banks are not for money, but for seeds. Why should seeds be saved? Saving seeds saves plants that may someday save human lives. These plants could provide food or medicine in the future. Throughout human history, many medicines have been developed from plants. And scientists keep searching for new chemicals among the incredible variety of plants in the world. But time is running out. Many plant species are becoming extinct before they have even been studied.

Math Activity

Many drugs were originally developed from plants. Suppose that 100 plants are used for medicines this year, but 5% of plant species become extinct each year. How many of the medicinal plants would be left after 1 year? after 10 years? Round your answers to whole numbers.



Science Fiction

"The Anatomy Lesson"
by Scott Sanders

Do you know the feeling you get when you have an important test? A medical student faces a similar situation in this story. The student needs to learn the bones of the human body for an anatomy exam the next day. The student goes to the anatomy library to study. The librarian lets him check out a box of bones that are supposed to be from a human skeleton. But something is wrong. There are too many bones. They are the wrong shape. They don't fit together correctly. Somebody must be playing a joke! Find out what's going on and why the student and the librarian will never be the same after "The Anatomy Lesson." You can read it in the *Holt Anthology of Science Fiction*.

Language Arts Activity

WRITING SKILL Before you read this story, predict what you think will happen. Write a paragraph that "gives away" the ending that you predict. After you have read the story, listen to some of the predictions made by your classmates. Discuss your opinions about the possible endings.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Raymond Pierotti

Canine Evolution Raymond Pierotti thinks that it's natural that he became an evolutionary biologist. He grew up exploring the desert around his home in New Mexico. He was fascinated by the abundant wildlife surviving in the bleak landscape. "One of my earliest memories is getting coyotes to sing with me from my backyard," he says.

Pierotti now studies the evolutionary relationships between wolves, coyotes, and domestic dogs. Some of his ideas come from the traditions of the Comanches. According to the Comanche creation story, humans came from wolves. Although Pierotti doesn't believe that humans evolved from wolves, he sees the creation story as a suggestion that humans and wolves have evolved together. "Wolves are very similar to humans in many ways," says Pierotti. "They live in family groups and hunt together. It is possible that wolves actually taught humans how to hunt in packs, and there are ancient stories of wolves and humans hunting together and sharing the food. I think it was this relationship that inspired the Comanche creation stories."

Social Studies ACTIVITY

WRITING SKILL Research a story of creation that comes from a Greek, Roman, or Native American civilization. Write a paragraph summarizing the myth, and share it with a classmate.

To learn more about these Science in Action topics, visit go.hrw.com and type in the keyword **HL5EVOF.**

Current Science

Check out Current Science® articles related to this chapter by visiting go.hrw.com. Just type in the keyword HL5CS07.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

LabBook

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Contents

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Skills Practice Lab

Mysterious Minerals

Imagine sitting on a rocky hilltop, gazing at the ground below you. You can see dozens of different types of rocks. How can scientists possibly identify the countless variations? It's a mystery!

In this activity, you'll use your powers of observation and a few simple tests to determine the identities of rocks and minerals. Take a look at the Mineral Identification Key on the next page. That key will help you use clues to discover the identity of several minerals.

MATERIALS

- gloves, protective
- iron filings
- minerals, samples
- slides, microscope, glass
- streak plate

SAFETY

Procedure

1. On a separate sheet of paper, create a data chart like the one below.
2. Choose one mineral sample, and locate its column in your data chart.
3. Follow the Mineral Identification Key to find the identity of your sample. When you are finished, record the mineral's name and primary characteristics in the appropriate column in your data chart. **Caution:** Put on your safety goggles and gloves when scratching the glass slide.
4. Select another mineral sample, and repeat steps 2 and 3 until your data table is complete.

Analyze the Results

1. Were some minerals easier to identify than others? Explain.
2. A streak test is a better indicator of a mineral's true color than visual observation is. Why isn't a streak test used to help identify every mineral?
3. On a separate sheet of paper, summarize what you learned about the various characteristics of each mineral sample you identified.

Mineral Summary Chart

Characteristics	1	2	3	4	5	6
Mineral name						
Luster						
Color						
Streak						
Hardness						
Cleavage						
Special properties						

DO NOT WRITE IN BOOK

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Mineral Identification Key

1. a. If your mineral has a metallic luster, **GO TO STEP 2.**
b. If your mineral has a nonmetallic luster, **GO TO STEP 3.**

2. a. If your mineral is black, **GO TO STEP 4.**
b. If your mineral is yellow, it is **PYRITE.**
c. If your mineral is silver, it is **GALENA.**

3. a. If your mineral is light in color, **GO TO STEP 5.**
b. If your mineral is dark in color, **GO TO STEP 6.**

4. a. If your mineral leaves a red-brown line on the streak plate, it is **HEMATITE.**
b. If your mineral leaves a black line on the streak plate, it is **MAGNETITE.** Test your sample for its magnetic properties by holding it near some iron filings.

5. a. If your mineral scratches the glass microscope slide, **GO TO STEP 7.**
b. If your mineral does not scratch the glass microscope slide, **GO TO STEP 8.**

6. a. If your mineral scratches the glass slide, **GO TO STEP 9.**
b. If your mineral does not scratch the glass slide, **GO TO STEP 10.**

7. a. If your mineral shows signs of cleavage, it is **ORTHOCLASE FELDSPAR.**
b. If your mineral does not show signs of cleavage, it is **QUARTZ.**

8. a. If your mineral shows signs of cleavage, it is **MUSCOVITE.** Examine this sample for twin sheets.
b. If your mineral does not show signs of cleavage, it is **GYPSUM.**

9. a. If your mineral shows signs of cleavage, it is **HORNBLENDE.**
b. If your mineral does not show signs of cleavage, it is **GARNET.**

10. a. If your mineral shows signs of cleavage, it is **BIOTITE.** Examine your sample for twin sheets.
b. If your mineral does not show signs of cleavage, it is **GRAPHITE.**

Applying Your Data

Using your textbook and other reference books, research other methods of identifying different types of minerals. Based on your findings, create a new identification key. Give the key and a few sample minerals to a friend, and see if your friend can unravel the mystery!

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Using Scientific Methods

Skills Practice Lab

Crystal Growth

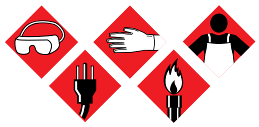
Magma forms deep below the Earth's surface at depths of 25 km to 160 km and at extremely high temperatures. Some magma reaches the surface and cools quickly. Other magma gets trapped in cracks or magma chambers beneath the surface and cools very slowly. When magma cools slowly, large, well-developed crystals form. But when magma erupts onto the surface, it cools more quickly. There is not enough time for large crystals to grow. The size of the crystals found in igneous rocks gives geologists clues about where and how the rocks formed.

In this experiment, you will demonstrate how the rate of cooling affects the size of crystals in igneous rocks by cooling crystals of magnesium sulfate at two different rates.

MATERIALS

- aluminum foil
- basalt
- beaker, 400 mL
- gloves, heat-resistant
- granite
- hot plate
- laboratory scoop, pointed
- magnesium sulfate ($MgSO_4$) (Epsom salts)
- magnifying lens
- marker, dark
- pumice
- tape, masking
- test tube, medium-sized
- thermometer, Celsius
- tongs, test-tube
- watch (or clock)
- water, distilled
- water, tap, 200 mL

SAFETY



Ask a Question

1. How does temperature affect the formation of crystals?

Form a Hypothesis

2. Suppose you have two solutions that are identical in every way except for temperature. How will the temperature of a solution affect the size of the crystals and the rate at which they form?

Test the Hypothesis

3. Put on your gloves, apron, and goggles.
4. Fill the beaker halfway with tap water. Place the beaker on the hot plate, and let it begin to warm. The temperature of the water should be between 40°C and 50°C. **Caution:** Make sure the hot plate is away from the edge of the lab table.
5. Examine two or three crystals of the magnesium sulfate with your magnifying lens. On a separate sheet of paper, describe the color, shape, luster, and other interesting features of the crystals.
6. On a separate sheet of paper, draw a sketch of the magnesium sulfate crystals.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

7 Use the pointed laboratory scoop to fill the test tube about halfway with the magnesium sulfate. Add an equal amount of distilled water.

8 Hold the test tube in one hand, and use one finger from your other hand to tap the test tube gently. Observe the solution mixing as you continue to tap the test tube.

9 Place the test tube in the beaker of hot water, and heat it for approximately 3 min. **Caution:** Be sure to direct the opening of the test tube away from you and other students.

10 While the test tube is heating, shape your aluminum foil into two small boatlike containers by doubling the foil and turning up each edge.

11 If all the magnesium sulfate is not dissolved after 3 min, tap the test tube again, and heat it for 3 min longer. **Caution:** Use the test-tube tongs to handle the hot test tube.

12 With a marker and a piece of masking tape, label one of your aluminum boats "Sample 1," and place it on the hot plate. Turn the hot plate off.

13 Label the other aluminum boat "Sample 2," and place it on the lab table.

14 Using the test-tube tongs, remove the test tube from the beaker of water, and evenly distribute the contents to each of your foil boats. Carefully pour the hot water in the beaker down the drain. Do not move or disturb either of your foil boats.

15 Copy the table below onto a separate sheet of paper. Using the magnifying lens, carefully observe the foil boats. Record the time it takes for the first crystals to appear.

Crystal-Formation Table

Crystal formation	Time	Size and appearance of crystals	Sketch of crystals
Sample 1			
Sample 2		DO NOT WRITE IN BOOK	

Copyright © by Holt, Rinehart and Winston. All rights reserved.

16. If crystals have not formed in the boats before class is over, carefully place the boats in a safe place. You may then record the time in days instead of in minutes.
17. When crystals have formed in both boats, use your magnifying lens to examine the crystals carefully.

Analyze the Results

1. Was your prediction correct? Explain.
2. Compare the size and shape of the crystals in Samples 1 and 2 with the size and shape of the crystals you examined in step 5. How long do you think the formation of the original crystals must have taken?

Draw Conclusions

3. Granite, basalt, and pumice are all igneous rocks. The most distinctive feature of each is the size of its crystals. Different igneous rocks form when magma cools at different rates. Examine a sample of each with your magnifying lens.
4. Copy the table below onto a separate sheet of paper, and sketch each rock sample.
5. Use what you have learned in this activity to explain how each rock sample formed and how long it took for the crystals to form. Record your answers in your table.




Igneous Rock Observations

	Granite	Basalt	Pumice
Sketch			
How did the rock sample form?		DO NOT WRITE IN BOOK	
Rate of cooling			

Communicating Your Data

Describe the size and shape of the crystals you would expect to find when a volcano erupts and sends material into the air and when magma oozes down the volcano's slope.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Model-Making Lab

Metamorphic Mash

Metamorphism is a complex process that takes place deep within the Earth, where the temperature and pressure would turn a human into a crispy pancake. The effects of this extreme temperature and pressure are obvious in some metamorphic rocks. One of these effects is the reorganization of mineral grains within the rock. In this activity, you will investigate the process of metamorphism without being charred, flattened, or buried.

MATERIALS

- cardboard (or plywood), very stiff, small pieces
- clay, modeling
- knife, plastic
- sequins (or other small flat objects)

SAFETY

Procedure

1. Flatten the clay into a layer about 1 cm thick. Sprinkle the surface with sequins.
2. Roll the corners of the clay toward the middle to form a neat ball.
3. Carefully use the plastic knife to cut the ball in half. On a separate sheet of paper, describe the position and location of the sequins inside the ball.
4. Put the ball back together, and use the sheets of cardboard or plywood to flatten the ball until it is about 2 cm thick.
5. Using the plastic knife, slice open the slab of clay in several places. Describe the position and location of the sequins in the slab.

Analyze the Results

1. What physical process does flattening the ball represent?
2. Describe any changes in the position and location of the sequins that occurred as the clay ball was flattened into a slab.

Draw Conclusions

3. How are the sequins oriented in relation to the force you put on the ball to flatten it?
4. Do you think the orientation of the mineral grains in a foliated metamorphic rock tells you anything about the rock? Defend your answer.

Applying Your Data

Suppose you find a foliated metamorphic rock that has grains running in two distinct directions. Use what you have learned in this activity to offer a possible explanation for this observation.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Using Scientific Methods

Model-Making Lab

Oh, the Pressure!

When scientists want to understand natural processes, such as mountain formation, they often make models to help them. Models are useful in studying how rocks react to the forces of plate tectonics. A model can demonstrate in a short amount of time geological processes that take millions of years. Do the following activity to find out how folding and faulting occur in the Earth's crust.

MATERIALS

- can, soup (or rolling pin)
- clay, modeling, 4 colors
- knife, plastic
- newspaper
- pencils, colored
- poster board, 5 cm × 5 cm squares (2)
- poster board, 5 cm × 15 cm strip

SAFETY

Ask a Question

1. How do synclines, anticlines, and faults form?

Form a Hypothesis

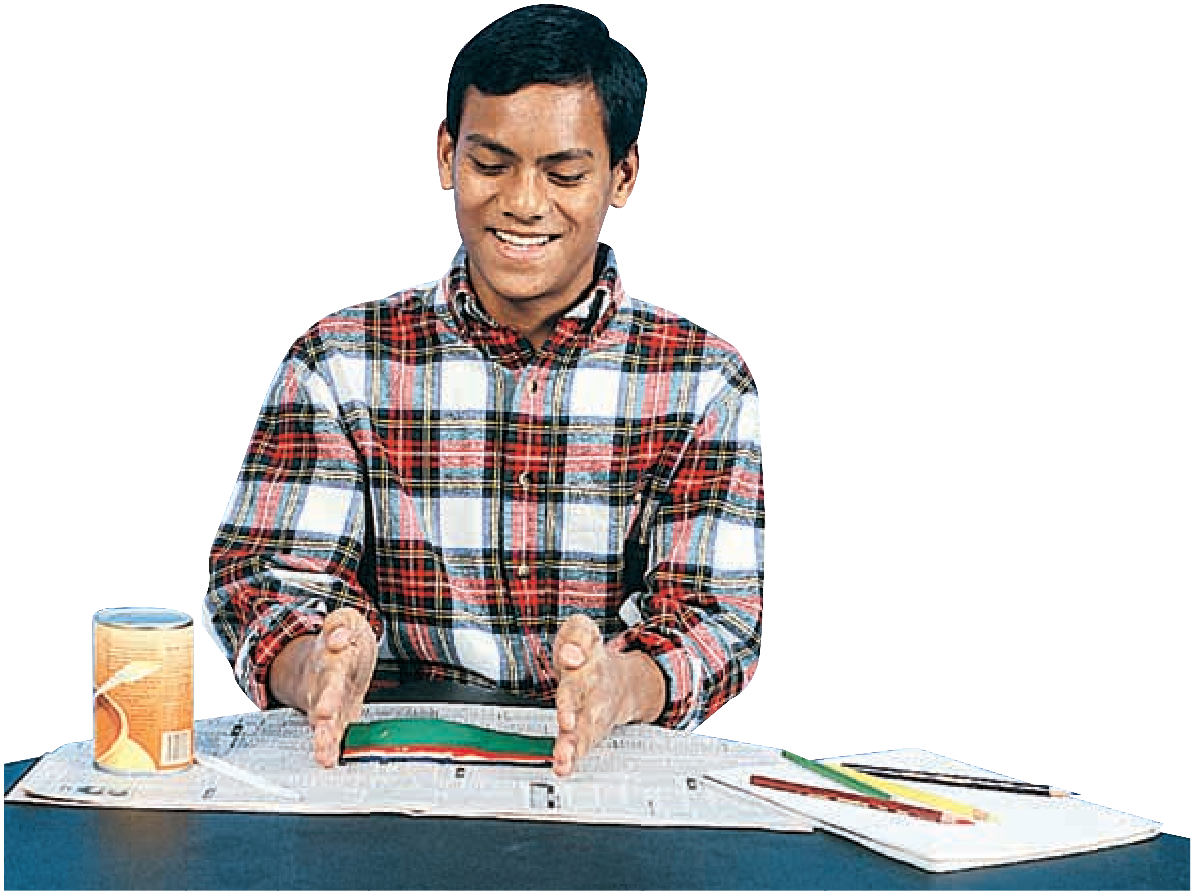
2. On a separate piece of paper, write a hypothesis that is a possible answer to the question above. Explain your reasoning.

Test the Hypothesis

3. Use modeling clay of one color to form a long cylinder, and place the cylinder in the center of the glossy side of the poster-board strip.
4. Mold the clay to the strip. Try to make the clay layer the same thickness all along the strip; you can use the soup can or rolling pin to even it out. Pinch the sides of the clay so that the clay is the same width and length as the strip. Your strip should be at least 15 cm long and 5 cm wide.

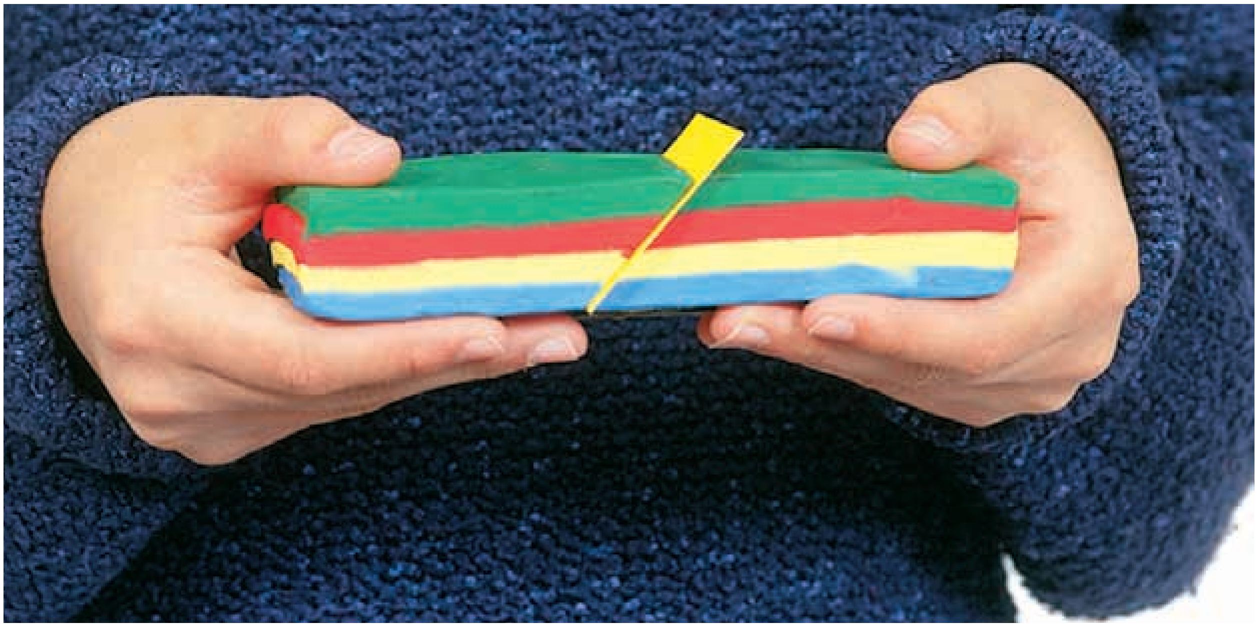
Copyright © by Holt, Rinehart and Winston. All rights reserved.

5. Flip the strip over on the newspaper your teacher has placed across your desk. Carefully peel the strip from the modeling clay.
6. Repeat steps 3–5 with the other colors of modeling clay. Each person should have a turn molding the clay. Each time you flip the strip over, stack the new clay layer on top of the previous one. When you are finished, you should have a block of clay made of four layers.
7. Lift the block of clay, and hold it parallel to and just above the tabletop. Push gently on the block from opposite sides, as shown below.



8. Use the colored pencils to draw the results of step 6. Use the terms *syncline* and *anticline* to label your diagram. Draw arrows to show the direction that each edge of the clay was pushed.
9. Repeat steps 3–6 to form a second block of clay.
10. Cut the second block of clay in two at a 45° angle as seen from the side of the block.

Copyright © by Holt, Rinehart and Winston. All rights reserved.



11 Press one poster-board square on the angled end of each of the block's two pieces. The poster board represents a fault. The two angled ends represent a hanging wall and a footwall. The model should resemble the one in the photograph above.

12 Keeping the angled edges together, lift the blocks, and hold them parallel to and just above the tabletop. Push gently on the two blocks until they move. Record your observations.

13 Now, hold the two pieces of the clay block in their original position, and slowly pull them apart, allowing the hanging wall to move downward. Record your observations.

Analyze the Results

1 What happened to the first block of clay in step 7? What kind of force did you apply to the block of clay?

2 What happened to the pieces of the second block of clay in step 12? What kind of force did you apply to them?

3 What happened to the pieces of the second block of clay in step 13? Describe the forces that acted on the block and the way the pieces of the block reacted.

Draw Conclusions

4 Summarize how the forces you applied to the blocks of clay relate to the way tectonic forces affect rock layers. Be sure to use the terms *fold, fault, anticline, syncline, hanging wall, footwall, tension,* and *compression* in your summary.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Skills Practice Lab

Earthquake Waves

The energy from an earthquake travels as seismic waves in all directions through the Earth. Seismologists can use the properties of certain types of seismic waves to find the epicenter of an earthquake.

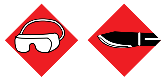
P waves travel more quickly than S waves and are always detected first. The average speed of P waves in the Earth's crust is 6.1 km/s. The average speed of S waves in the Earth's crust is 4.1 km/s. The difference in arrival time between P waves and S waves is called *lag time.*

In this activity, you will use the S-P-time method to determine the location of an earthquake's epicenter.

MATERIALS

- calculator (optional)
- compass
- ruler, metric

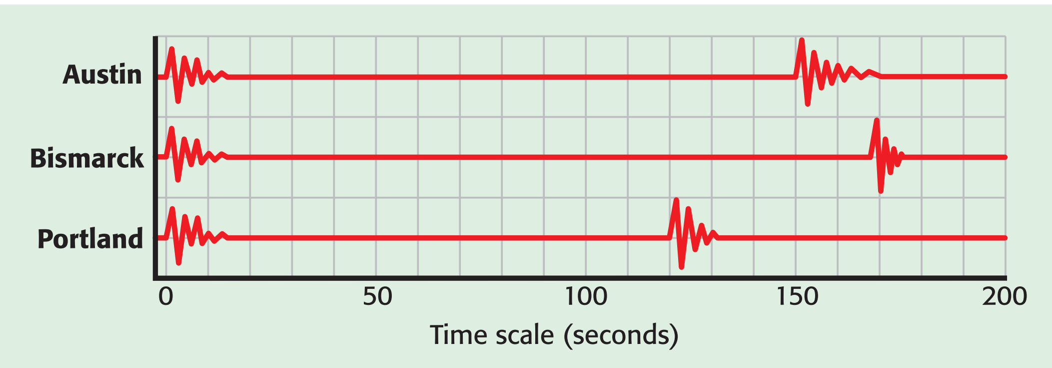
SAFETY



Procedure

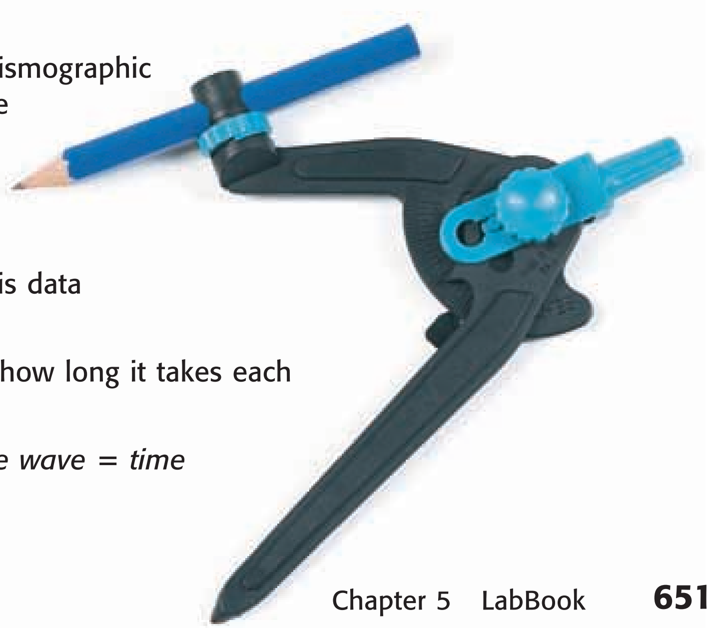
1. The illustration below shows seismographic records made in three cities following an earthquake. These traces begin at the left and show the arrival of P waves at time zero. The second set of waves on each record represents the arrival of S waves.

Seismographic Records



2. Copy the data table on the next page.
3. Use the time scale provided with the seismographic records to find the lag time between the P waves and the S waves for each city. Remember that the lag time is the time between the moment when the first P wave arrives and the moment when the first S wave arrives. Record this data in your table.
4. Use the following equation to calculate how long it takes each wave type to travel 100 km:

$$100 \text{ km} \div \textit{average speed of the wave} = \textit{time}$$



Copyright © by Holt, Rinehart and Winston. All rights reserved.

5. To find lag time for earthquake waves at 100 km, subtract the time it takes P waves to travel 100 km from the time it takes S waves to travel 100 km. Record the lag time.

6. Use the following formula to find the distance from each city to the epicenter:

$$distance = \frac{measured\ lag\ time\ (s) \times 100\ \text{km}}{lag\ time\ for\ 100\ km\ (s)}$$

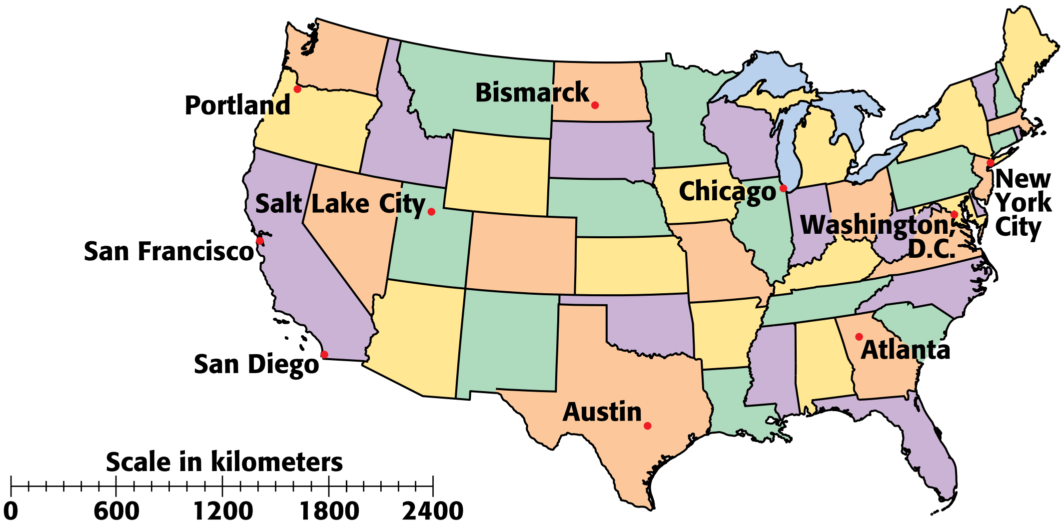
In your data table, record the distance from each city to the epicenter.

Epicenter Data Table		
City	**Lag time (seconds)**	**Distance to the epicenter (km)**
Austin, TX		
Bismarck, ND		
Portland, OR		

DO NOT WRITE IN BOOK

7. Trace the map below onto a separate sheet of paper.

8. Use the scale to adjust your compass so that the radius of a circle with Austin at the center is equal to the distance between Austin and the epicenter of the earthquake.



9. Put the point of your compass at Austin on your copy of the map, and draw a circle.

10. Repeat steps 8 and 9 for Bismarck and Portland. The epicenter of the earthquake is located near the point where the three circles meet.

Anayze the Results

1. Which city is closest to the epicenter?

Draw Conclusions

2. Why do seismologists need measurements from three different locations to find the epicenter of an earthquake?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Skills Practice Lab

Some Go "Pop," Some Do Not

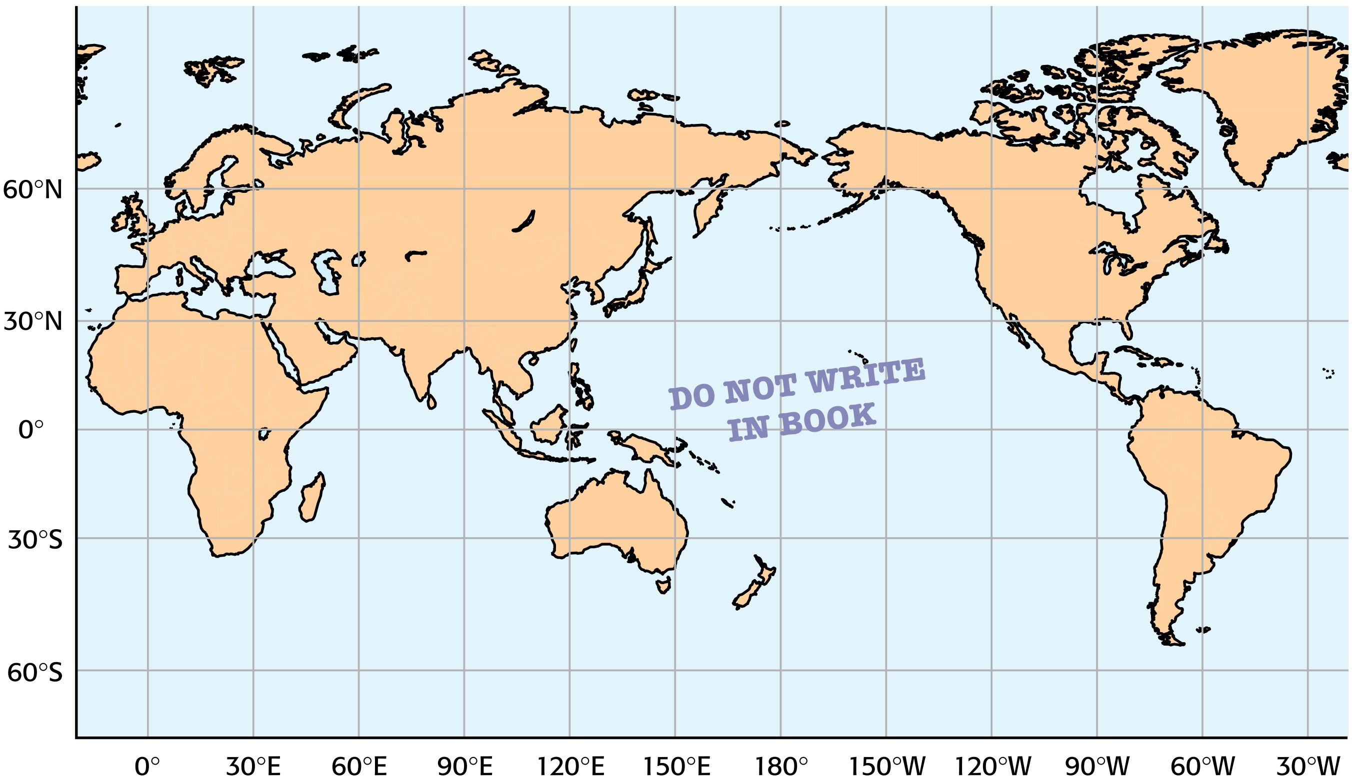
Volcanic eruptions range from mild to violent. When volcanoes erupt, the materials left behind provide information to scientists studying the Earth's crust. Mild, or nonexplosive, eruptions produce thin, runny lava that is low in silica. During nonexplosive eruptions, lava simply flows down the side of the volcano. Explosive eruptions, on the other hand, do not produce much lava. Instead, the explosions hurl ash and debris into the air. The materials left behind are light in color and high in silica. These materials help geologists determine the composition of the crust underneath the volcanoes.

MATERIALS

- paper, graph (1 sheet)
- pencils (or markers), red, yellow, and orange
- ruler, metric

Procedure

1. Copy the map below onto graph paper. Take care to line the grid up properly.
2. Locate each volcano from the list on the next page by drawing a circle with a diameter of about 2 mm in the proper location on your copy of the map. Use the latitude and longitude grids to help you.
3. Review all the eruptions for each volcano. For each explosive eruption, color the circle red. For each quiet volcano, color the circle yellow. For volcanoes that have erupted in both ways, color the circle orange.



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Volcanic Activity Chart

Volcano name	Location	Description
Mount St. Helens	46°N 122°W	An explosive eruption blew the top off the mountain. Light-colored ash covered thousands of square kilometers. Another eruption sent a lava flow down the southeast side of the mountain.
Kilauea	19°N 155°W	One small eruption sent a lava flow along 12 km of highway.
Rabaul caldera	4°S 152°E	Explosive eruptions have caused tsunamis and have left 1–2 m of ash on nearby buildings.
Popocatépetl	19°N 98°W	During one explosion, Mexico City closed the airport for 14 hours because huge columns of ash made it too difficult for pilots to see. Eruptions from this volcano have also caused damaging avalanches.
Soufriere Hills	16°N 62°W	Small eruptions have sent lava flows down the hills. Other explosive eruptions have sent large columns of ash into the air.
Long Valley caldera	37°N 119°W	Explosive eruptions have sent ash into the air.
Okmok	53°N 168°W	Recently, there have been slow lava flows from this volcano. Twenty-five hundred years ago, ash and debris exploded from the top of this volcano.
Pavlof	55°N 161°W	Eruption clouds have been sent 200 m above the summit. Eruptions have sent ash columns 10 km into the air. Occasionally, small eruptions have caused lava flows.
Fernandina	42°N 12°E	Eruptions have ejected large blocks of rock from this volcano.
Mount Pinatubo	15°N 120°E	Ash and debris from an explosive eruption destroyed homes, crops, and roads within 52,000 km^2 around the volcano.

Analyze the Results

1. According to your map, where are volcanoes that always have nonexplosive eruptions located?
2. Where are volcanoes that always erupt explosively located?
3. Where are volcanoes that erupt in both ways located?
4. If volcanoes get their magma from the crust below them, what can you say about the silica content of Earth's crust under the oceans?
5. What is the composition of the crust under the continents? How do we know?

Draw Conclusions

6. What is the source of materials for volcanoes that erupt in both ways? How do you know?
7. Do the locations of volcanoes that erupt in both ways make sense, based on your answers to questions 4 and 5? Explain.

Applying Your Data

Volcanoes are present on other planets. If a planet had only nonexplosive volcanoes on its surface, what would we be able to infer about the planet? If a planet had volcanoes that ranged from nonexplosive to explosive, what might that tell us about the planet?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Using Scientific Methods

Skills Practice Lab

Great Ice Escape

Did you know that ice acts as a natural wrecking ball? Even rocks don't stand a chance against the power of ice. When water trapped in rock freezes, a process called *ice wedging* occurs. The water volume increases, and the rock cracks to "get out of the way." This expansion can fragment a rock into several pieces. In this exercise, you will see how this natural wrecker works, and you will try to stop the great ice escape.

MATERIALS

- bags, sandwich resealable (3)
- freezer
- jars, hard plastic with screw-on lids, such as spice containers (3)
- ruler, metric
- tape, strings, rubber bands, and other items to bind or reinforce the jars
- water

SAFETY

Ask a Question

1. If a plastic jar is filled with water, is there a way to prevent the jar from breaking when the water freezes?

Form a Hypothesis

2. Write a hypothesis that is a possible answer to the question above. Explain your reasoning.

Test the Hypothesis

3. Fill three identical jars to overflowing with water, and close two of them securely.
4. Measure the height of the water in the unsealed container. Record the height.
5. Tightly wrap one of the closed jars with tape, string, or other items to reinforce the jar. These items must be removable.
6. Place all three jars in resealable sandwich bags, and leave them in the freezer overnight. (Make sure the open jar does not spill.)
7. Remove the jars from the freezer, and carefully remove the wrapping from the reinforced jar.
8. Did your reinforced jar crack? Why or why not?
9. What does each jar look like? Record your observations.
10. Record the height of the ice in the unsealed jar. How does the new height compare with the height you measured in step 4?

Analyze the Results

1. Do you think it is possible to stop the ice from breaking the sealed jars? Why or why not?
2. How could ice wedging affect soil formation?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Model-Making Lab

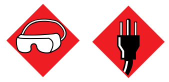
Dune Movement

Wind moves the sand by a process called *saltation.* The sand skips and bounces along the ground in the same direction as the wind is blowing. As sand is blown across a beach, the dunes change. In this activity, you will investigate the effect wind has on a model sand dune.

MATERIALS

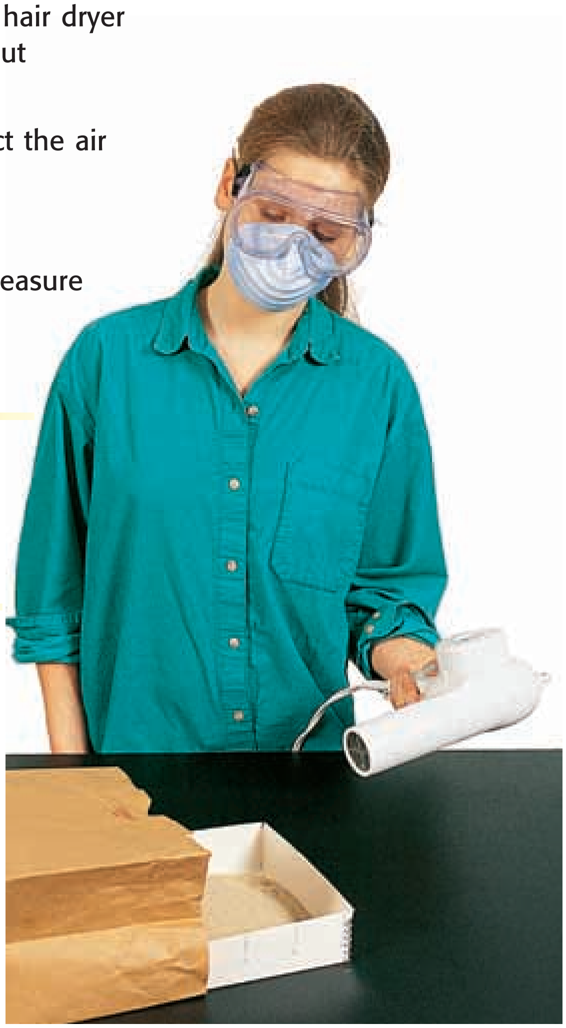
- bag, paper, large enough to hold half the box
- box, cardboard, shallow
- hair dryer
- marker
- mask, filter
- ruler, metric
- sand, fine

SAFETY



Procedure

1. Use the marker to draw and label vertical lines 5 cm apart along one side of the box.
2. Fill the box about halfway with sand. Brush the sand into a dune shape about 10 cm from the end of the box.
3. Use the lines you drew along the edge of the box to measure the location of the dune's peak to the nearest centimeter.
4. Slide the box into the paper bag until only about half the box is exposed, as shown below.
5. Put on your safety goggles and filter mask. Hold the hair dryer so that it is level with the peak of the dune and about 10–20 cm from the open end of the box.
6. Turn on the hair dryer at the lowest speed, and direct the air toward the model sand dune for 1 min.
7. Record the new location of the model dune.
8. Repeat steps 5 and 6 three times. After each trial, measure and record the location of the dune's peak.



Analyze the Results

1. How far did the dune move during each trial?
2. How far did the dune move overall?

Draw Conclusions

3. How might the dune's movement be affected if you were to turn the hair dryer to the highest speed?

Applying Your Data

Flatten the sand. Place a barrier, such as a rock, in the sand. Position the hair dryer level with the top of the sand's surface. How does the rock affect the dune's movement?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Using Scientific Methods

Skills Practice Lab

Creating a Kettle

As glaciers recede, they leave huge amounts of rock material behind. Sometimes receding glaciers form moraines by depositing some of the rock material in ridges. At other times, glaciers leave chunks of ice that form depressions called *kettles*. As the ice melts, these depressions may form ponds or lakes. In this activity, you will discover how kettles are formed by creating your own.

MATERIALS

- ice, cubes of various sizes (4–5)
- ruler, metric
- sand
- tub, small

Ask a Question

1. How are kettles formed?

Form a Hypothesis

2. Write a hypothesis that could answer the question above.

Test the Hypothesis

3. Fill the tub three-quarters full with sand.
4. Describe the size and shape of each ice cube.
5. Push the ice cubes to various depths in the sand.
6. Put the tub where it won't be disturbed overnight.
7. Closely observe the sand around the area where you left each ice cube.
8. What happened to the ice cubes?
9. Use a metric ruler to measure the depth and diameter of the indentation left by each ice cube.

Analyze the Results

1. How does this model relate to the size and shape of a natural kettle?
2. In what ways are your model kettles similar to real ones? How are they different?

Draw Conclusions

3. Based on your model, what can you conclude about the formation of kettles by receding glaciers?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Model-Making Lab

Eclipses

As the Earth and the moon revolve around the sun, they both cast shadows into space. An eclipse occurs when one planetary body passes through the shadow of another. You can demonstrate how an eclipse occurs by using clay models of planetary bodies.

MATERIALS

- clay, modeling
- flashlight, small
- paper, notebook (1 sheet)
- ruler, metric

Procedure

1. Make two balls out of the modeling clay. One ball should have a diameter of about 4 cm and will represent the Earth. The other should have a diameter of about 1 cm and will represent the moon.
2. Place the two balls about 15 cm apart on the sheet of paper. (You may want to prop the smaller ball up on folded paper or on clay so that the centers of the two balls are at the same level.)
3. Hold the flashlight approximately 15 cm away from the large ball. The flashlight and the two balls should be in a straight line. Keep the flashlight at about the same level as the clay. When the whole class is ready, your teacher will turn off the lights.
4. Turn on your flashlight. Shine the light on the larger ball, and sketch your model. Include the beam of light in your drawing.
5. Move the flashlight to the opposite side of the paper. The flashlight should now be approximately 15 cm away from the smaller clay ball. Repeat step 4.

Analyze the Results

1. What does the flashlight in your model represent?
2. As viewed from Earth, what event did your model represent in step 4?
3. As viewed from the moon, what event did your model represent in step 4?
4. As viewed from Earth, what event did your model represent in step 5?
5. As viewed from the moon, what event did your model represent in step 5?
6. According to your model, how often would solar and lunar eclipses occur? Is this accurate? Explain.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Skills Practice Lab

Phases of the Moon

It's easy to see when the moon is full. But you may have wondered exactly what happens when the moon appears as a crescent or when you cannot see the moon at all. Does the Earth cast its shadow on the moon? In this activity, you will discover how and why the moon appears as it does in each phase.

MATERIALS

- ball, plastic-foam
- globe, world
- light source

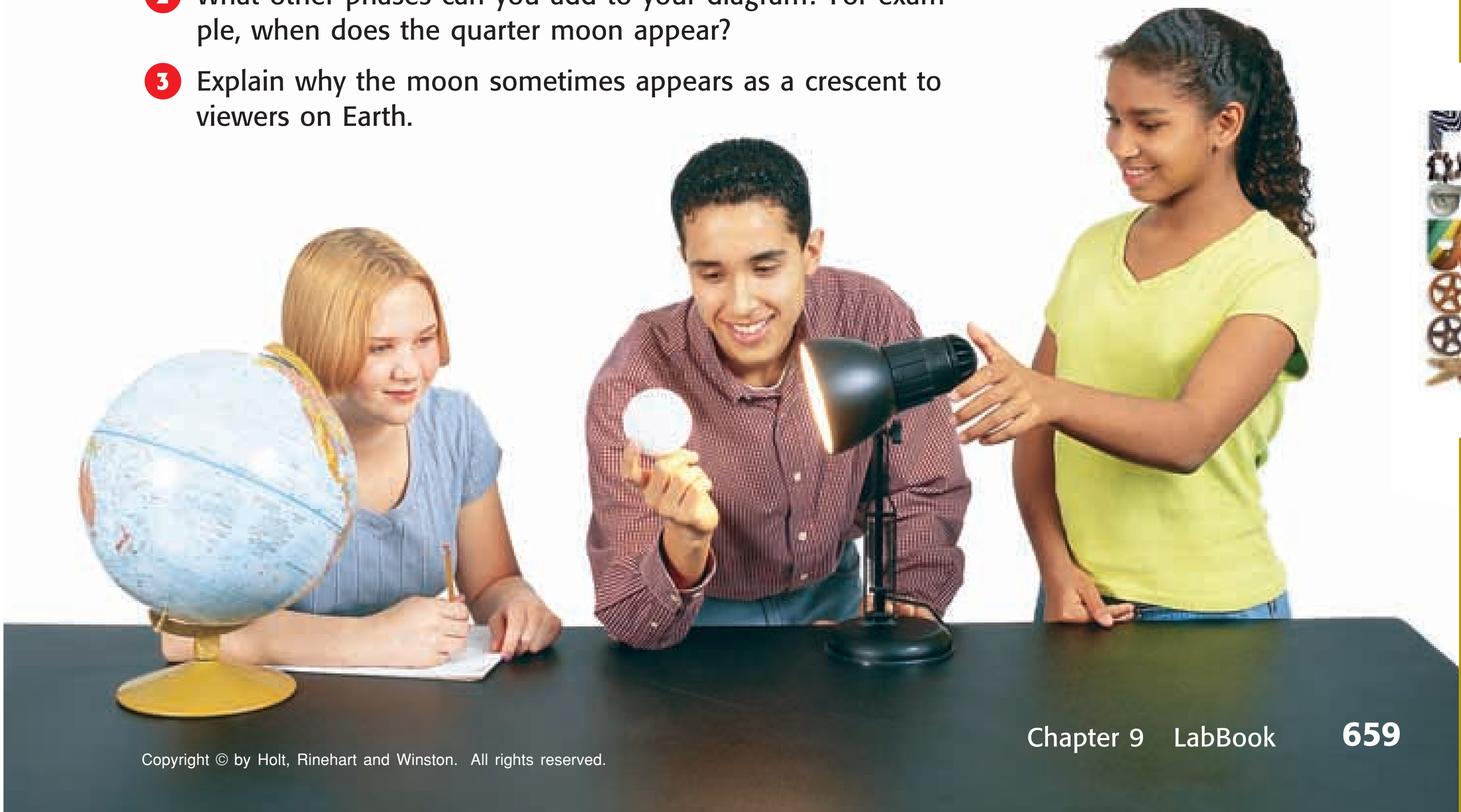
SAFETY

Procedure

1. Place your globe near the light source. Be sure that the north pole is tilted toward the light. Rotate the globe so that your state faces the light.
2. Using the ball as your model of the moon, move the moon between the Earth (the globe) and the sun (the light). The side of the moon that faces the Earth will be in darkness. Write your observations of this new-moon phase.
3. Continue to move the moon in its orbit around the Earth. When part of the moon is illuminated by the light, as viewed from Earth, the moon is in the crescent phase. Record your observations.
4. If you have time, you may draw your own moon-phase diagram.

Analyze the Results

1. About 2 weeks after the new moon appears, the entire moon is visible in the sky. Move the ball to show this event.
2. What other phases can you add to your diagram? For example, when does the quarter moon appear?
3. Explain why the moon sometimes appears as a crescent to viewers on Earth.



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Using Scientific Methods

Model-Making Lab

Why Do They Wander?

Before the discoveries of Nicholas Copernicus in the early 1500s, most people thought that the planets and the sun revolved around the Earth and that the Earth was the center of the solar system. But Copernicus observed that the sun is the center of the solar system and that all the planets, including Earth, revolve around the sun. He also explained a puzzling aspect of the movement of planets across the night sky.

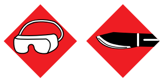
If you watch a planet every night for several months, you'll notice that it appears to "wander" among the stars. While the stars remain in fixed positions relative to each other, the planets appear to move independently of the stars. Mars first travels to the left, then back to the right, and then again to the left.

In this lab, you will make your own model of part of the solar system to find out how Copernicus's model of the solar system explained this zigzag motion of the planets.

MATERIALS

- compass, drawing
- paper, white
- pencils, colored
- ruler, metric

SAFETY



Ask a Question

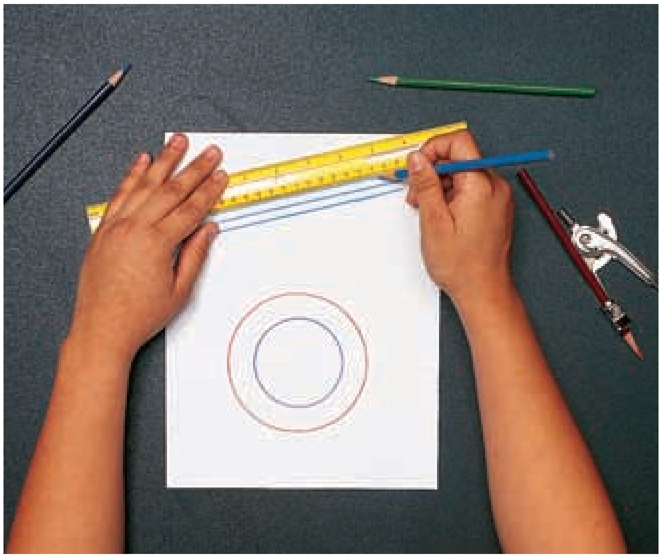
1. Why do the planets appear to move back and forth in the Earth's night sky?

Form a Hypothesis

2. Write a possible answer to the question above.

Test the Hypothesis

3. Use the compass to draw a circle with a diameter of 9 cm on the paper. This circle will represent the orbit of the Earth around the sun. (Note: The orbits of the planets are actually slightly elliptical, but circles will work for this activity.)
4. Using the same center point, draw a circle with a diameter of 12 cm. This circle will represent the orbit of Mars.
5. Using a blue pencil, draw three parallel lines diagonally across one end of your paper, as shown at right. These lines will help you plot the path Mars appears to travel in Earth's night sky. Turn your paper so the diagonal lines are at the top of the page.



Copyright © by Holt, Rinehart and Winston. All rights reserved.

6. Place 11 dots 2.5 cm apart from each other on your Earth orbit. Number the dots 1 through 11. These dots will represent Earth's position from month to month.

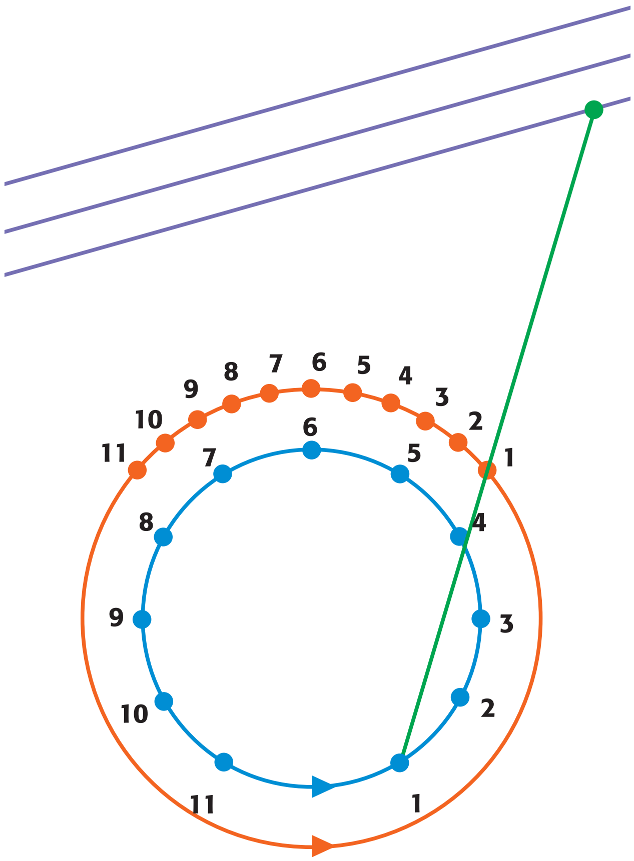
7. Now, place 11 dots along the top of your Mars orbit 0.5 cm apart from each other. Number the dots as shown. These dots will represent the position of Mars at the same time intervals. Notice that Mars travels slower than Earth.

8. Draw a green line to connect the first dot on Earth's orbit to the first dot on Mars's orbit. Extend this line to the first diagonal line at the top of your paper. Place a green dot where the green line meets the first blue diagonal line. Label the green dot "1."

9. Now, connect the second dot on Earth's orbit to the second dot on Mars's orbit, and extend the line all the way to the first diagonal at the top of your paper. Place a green dot where this line meets the first blue diagonal line, and label this dot "2."

10. Continue drawing green lines from Earth's orbit through Mars's orbit and finally to the blue diagonal lines. Pay attention to the pattern of dots you are adding to the diagonal lines. When the direction of the dots changes, extend the green line to the next diagonal line, and add the dots to that line instead.

11. When you are finished adding green lines, draw a red line to connect all the green dots on the blue diagonal lines in the order you drew them.



Analyze the Results

1. What do the green lines connecting points along Earth's orbit and Mars's orbit represent?

2. What does the red line connecting the dots along the diagonal lines look like? How can you explain this?

Draw Conclusions

3. What does this demonstration show about the motion of Mars?

4. Why do planets appear to move back and forth across the sky?

5. Were the Greeks justified in calling the planets *wanderers*? Explain.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Using Scientific Methods

Model-Making Lab

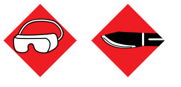
Reach for the Stars

Have you ever thought about living and working in space? Well, in order for you to do so, you would have to learn to cope with the new environment and surroundings. At the same time that astronauts are adjusting to the topsy-turvy conditions of space travel, they are also dealing with special tools used to repair and build space stations. In this activity, you will get the chance to model one tool that might help astronauts work in space.

MATERIALS

- ball, plastic-foam
- box, cardboard
- hole punch
- paper brads (2)
- paper clips, jumbo (2)
- ruler, metric
- scissors
- wire, metal

SAFETY



Ask a Question

1. How can I build a piece of equipment that models how astronauts work in space?

Form a Hypothesis

2. Write a possible answer for the question above. Describe a possible tool that would help astronauts work in space.

Test the Hypothesis

3. Cut three strips from the cardboard box. Each strip should be about 5 cm wide. The strips should be at least 20 cm long but not longer than 40 cm.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

4. Punch holes near the center of each end of the three cardboard strips. The holes should be about 3 cm from the end of each strip.
5. Lay the strips end to end along your table. Slide the second strip toward the first strip so that a hole in the first strip lines up with a hole in the second strip. Slip a paper brad through the holes, and bend its ends out to attach the cardboard strips.
6. Use another brad to attach the third cardboard strip to the free end of the second strip. Now, you have your mechanical arm. The paper brads create joints where the cardboard strips meet.
7. Straighten the wire, and slide it through the hole in one end of your mechanical arm. Bend about 3 cm of the wire in a 90° angle so that it will not slide back out of the hole.
8. Now, try to move the arm by holding the free ends of the cardboard and wire. The arm should bend and straighten at the joints. If it is difficult to move your mechanical arm, adjust the design. Consider loosening the brads, for example.
9. Your mechanical arm now needs a hand. Otherwise, it won't be able to pick things up! Straighten one paper clip, and slide it through the hole where you attached the wire in step 7. Bend one end of the paper clip to form a loop around the cardboard and the other end to form a hook. You will use this hook to pick things up.
10. Bend a second paper clip into a U shape. Stick the straight end of this paper clip into the foam ball. Leave the ball on your desk.
11. Move your mechanical arm so that you can lift the foam ball. The paper-clip hook on the mechanical arm will have to catch the paper clip on the ball.

Analyze the Results

1. Did you have any trouble moving the mechanical arm in step 8? What adjustments did you make?
2. Did you have trouble picking up the foam ball? What might have made picking up the ball easier?

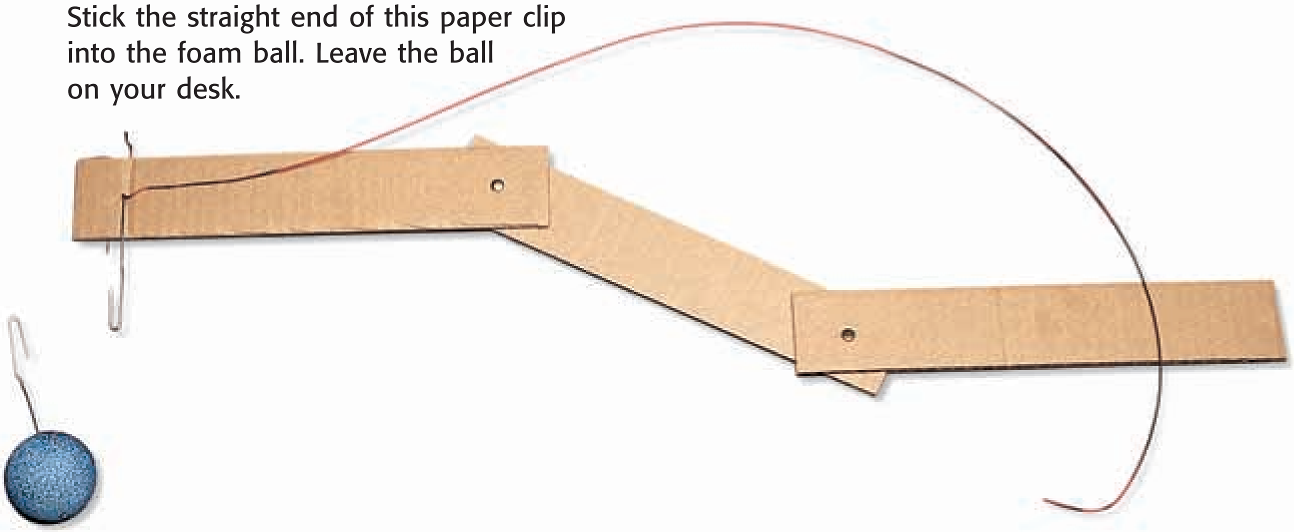
Draw Conclusions

3. What improvements could you make to your mechanical arm that might make it easier to use?
4. How would a tool like this one help astronauts work in space?

Applying Your Data

Adjust the design for your mechanical arm. Can you find a way to lift objects other than the foam ball? For example, can you lift heavier objects or objects that do not have a loop attached? How?

Research the tools that astronauts use on space stations and on the space shuttle. How do their tools help them work in the special conditions of space?



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Skills Practice Lab

Energy of a Pendulum

A pendulum clock is a compound machine that uses stored energy to do work. A spring stores energy, and with each swing of the pendulum, some of that stored energy is used to move the hands of the clock. In this lab, you will take a close look at the energy conversions that occur as a pendulum swings.

MATERIALS

- marker
- mass, hooked, 100 g
- meterstick
- string, 1 m

SAFETY

Procedure

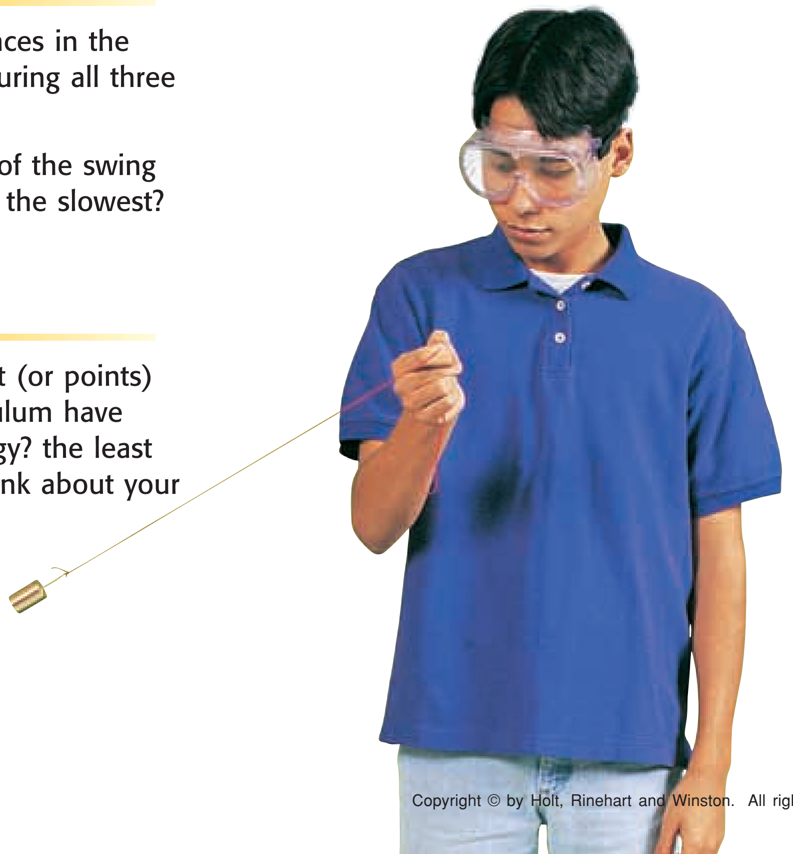
1. Make a pendulum by tying the string around the hook of the mass. Use the marker and the meterstick to mark points on the string that are 50 cm, 70 cm, and 90 cm away from the mass.
2. Hold the string at the 50 cm mark. Gently pull the mass to the side, and release it without pushing it. Observe at least 10 swings of the pendulum.
3. Record your observations. Be sure to note how fast and how high the pendulum swings.
4. Repeat steps 2 and 3 while holding the string at the 70 cm mark and again while holding the string at the 90 cm mark.

Analyze the Results

1. List similarities and differences in the motion of the pendulum during all three trials.
2. At which point (or points) of the swing was the pendulum moving the slowest? the fastest?

Draw Conclusions

3. In each trial, at which point (or points) of the swing did the pendulum have the greatest potential energy? the least potential energy? (Hint: Think about your answers to question 2.)
4. At which point (or points) of the swing did the pendulum have the greatest kinetic energy? the least kinetic energy? Explain your answers.
5. Describe the relationship between the pendulum's potential energy and its kinetic energy on its way down. Explain.
6. What improvements might reduce the amount of energy used to overcome friction so that the pendulum would swing for a longer period of time?



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Using Scientific Methods

Inquiry Lab

Save the Cube!

The biggest enemy of an ice cube is the transfer of thermal energy—heat. Energy can be transferred to an ice cube in three ways: conduction (the transfer of energy through direct contact), convection (the transfer of energy by the movement of a liquid or gas), and radiation (the transfer of energy through matter or space). Your challenge in this activity is to design a way to protect an ice cube as much as possible from all three types of energy transfer.

MATERIALS

- bag, plastic, small
- balance, metric
- cup, plastic or paper, small
- ice cube
- milk carton, empty, half-pint
- assorted materials provided by your teacher

Ask a Question

1. What materials prevent energy transfer most efficiently?

Form a Hypothesis

2. Design a system that protects an ice cube against each type of energy transfer. Describe your proposed design.

Test the Hypothesis

3. Use a plastic bag to hold the ice cube and any water if the ice cube melts. You may use any of the materials to protect the ice cube. The whole system must fit inside a milk carton.
4. Find the mass of the empty cup, and record it. Then, find and record the mass of an empty plastic bag.
5. Find and record the mass of the ice cube and cup together.
6. Quickly wrap the bag (and the ice cube inside) in its protection. Remember that the package must fit in the milk carton.
7. Place your ice cube in the "thermal zone" set up by your teacher. After 10 min, remove the ice cube from the zone.
8. Open the bag. Pour any water into the cup. Find and record the mass of the cup and water together.
9. Find and record the mass of the water by subtracting the mass of the empty cup from the mass of the cup and water.
10. Use the same method to determine the mass of the ice cube.
11. Using the following equation, find and record the percentage of the ice cube that melted:

$$\%\ melted = \frac{mass\ of\ water}{mass\ of\ ice\ cube} \times 100$$

Analyze the Results

1. Compared with other designs in your class, how well did your design protect against each type of energy transfer? How could you improve your design?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Model-Making Lab

Counting Calories

Energy transferred by heat is often expressed in units called *calories.* In this lab, you will build a model of a device called a *calorimeter.* Scientists often use calorimeters to measure the amount of energy that can be transferred by a substance. In this experiment, you will construct your own calorimeter and test it by measuring the energy released by a hot penny.

MATERIALS

- cup, plastic-foam, large
- cup, plastic-foam, small, with lid
- graduated cylinder, 100 mL
- heat source
- penny
- stopwatch
- thermometer
- tongs
- water

SAFETY

Procedure

1. Copy the table below.

Data Collection Table									
Seconds	0	15	30	45	60	75	90	105	120
Water temperature (°C)			DO NOT WRITE IN BOOK						

2. Place the lid on the small plastic-foam cup, and insert a thermometer through the hole in the top of the lid. (The thermometer should not touch the bottom of the cup.) Place the small cup inside the large cup to complete the calorimeter.
3. Remove the lid from the small cup, and add 50 mL of room-temperature water to the cup. Measure the water's temperature, and record the value in the first column (0 s) of the table.
4. Using tongs, heat the penny carefully. Add the penny to the water in the small cup, and replace the lid. Start your stopwatch.
5. Every 15 s, measure and record the temperature. Gently swirl the large cup to stir the water, and continue recording temperatures for 2 min (120 s).

Analyze the Results

1. What was the total temperature change of the water after 2 min?
2. The number of calories absorbed by the water is the mass of the water (in grams) multiplied by the temperature change (in °C) of the water. How many calories were absorbed by the water? (Hint: 1 mL water = 1 g water)
3. In terms of heat, explain where the calories to change the water temperature came from.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Skills Practice Lab

Wave Speed, Frequency, and Wavelength

Wave speed, frequency, and wavelength are three related properties of waves. In this lab, you will make observations and collect data to determine the relationship among these properties.

MATERIALS

- meterstick
- stopwatch
- toy, coiled spring

SAFETY

Part A: Wave Speed

Procedure

1. Copy Table 1.

Table 1 **Wave Speed Data**

Trial	Length of spring (m)	Time for wave (s)	Speed of wave (m/s)
1			
2			
3		DO NOT WRITE IN BOOK	
Average			

2. Two students should stretch the spring to a length of 2 m to 4 m on the floor or on a table. A third student should measure the length of the spring. Record the length in Table 1.
3. One student should pull part of the spring sideways with one hand, as shown at right, and release the pulled-back portion. This action will cause a wave to travel down the spring.
4. Using a stopwatch, the third student should measure how long it takes for the wave to travel down the length of the spring and back. Record this time in Table 1.
5. Repeat steps 3 and 4 two more times.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Part B: Wavelength and Frequency

Procedure

1. Keep the spring the same length that you used in Part A.
2. Copy Table 2.

Table 2 Wavelength and Frequency Data

Trial	Length of spring (m)	Time for 10 cycles (s)	Wave frequency (Hz)	Wavelength (m)
1				
2				
3		DO NOT WRITE IN BOOK		
Average				

3. One of the two students holding the spring should start shaking the spring from side to side until a wave pattern appears that resembles one of those shown.
4. Using the stopwatch, the third student should measure and record how long it takes for 10 cycles of the wave pattern to occur. (One back-and-forth shake is 1 cycle.) Keep the pattern going so that measurements for three trials can be made.

Analyze the Results

Part A

1. Calculate and record the wave speed for each trial. (Speed equals distance divided by time; distance is twice the spring length.)
2. Calculate and record the average time and the average wave speed.

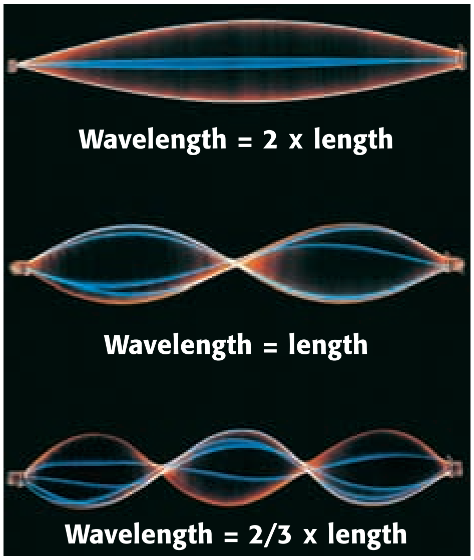
Part B

3. Calculate the frequency for each trial by dividing the number of cycles (10) by the time. Record the answers in Table 2.
4. Determine the wavelength using the equation at right that matches your wave pattern. Record your answer in Table 2.
5. Calculate and record the average time and frequency.

Draw Conclusions: Parts A and B

6. Analyze the relationship among speed, wavelength, and frequency. Multiply or divide any two of them to see if the result equals the third. (Use the averages from your data tables.) Write the equation that shows the relationship.

Wave Patterns



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Inquiry Lab

The Speed of Sound

In the chapter entitled "The Nature of Sound," you learned that the speed of sound in air is 343 m/s at 20°C (approximately room temperature). In this lab, you'll design an experiment to measure the speed of sound yourself—and you'll determine if you're "up to speed"!

MATERIALS

- items to be determined by the students and approved by the teacher

Procedure

1. Brainstorm with your teammates to come up with a way to measure the speed of sound. Consider the following as you design your experiment:

   a. You must have a method of making a sound. Some simple examples include speaking, clapping your hands, and hitting two boards together.

   b. Remember that speed is equal to distance divided by time. You must devise methods to measure the distance that a sound travels and to measure the amount of time it takes for that sound to travel that distance.

   c. Sound travels very rapidly. A sound from across the room will reach your ears almost before you can start recording the time! You may wish to have the sound travel a long distance.

   d. Remember that sound travels in waves. Think about the interactions of sound waves. You might be able to include these interactions in your design.

2. Discuss your experimental design with your teacher, including any equipment you need. Your teacher may have questions that will help you improve your design.

3. Once your design is approved, carry out your experiment. Be sure to perform several trials. Record your results.

Analyze the Results

1. Was your result close to the value given in the introduction to this lab? If not, what factors may have caused you to get such a different value?

2. Why was it important for you to perform several trials in your experiment?

Draw Conclusions

3. Compare your results with those of your classmates. Determine which experimental design provided the best results. Explain why you think this design was so successful.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Skills Practice Lab

Tuneful Tube

If you have seen a singer shatter a crystal glass simply by singing a note, you have seen an example of resonance. For the glass to shatter, the note has to match the resonant frequency of the glass. A column of air within a cylinder can also resonate if the air column is the proper length for the frequency of the note. In this lab, you will investigate the relationship between the length of an air column, the frequency, and the wavelength during resonance.

MATERIALS

- eraser, pink, rubber
- graduated cylinder, 100 mL
- paper, graph
- plastic tube, supplied by your teacher
- ruler, metric
- tuning forks, different frequencies (4)
- water

SAFETY

Procedure

1. Copy the data table below.

Data Collection Table

Frequency (Hz)				
Length (cm)				

DO NOT WRITE IN BOOK

2. Fill the graduated cylinder with water.
3. Hold a plastic tube in the water so that about 3 cm is above the water.
4. Record the frequency of the first tuning fork. Gently strike the tuning fork with the eraser, and hold the tuning fork so that the prongs are just above the tube, as shown at right. Slowly move the tube
and fork up and down until you hear the loudest sound.
5. Measure the distance from the top of the tube to the water. Record this length in your data table.
6. Repeat steps 3–5 using the other three tuning forks.

Analyze the Results

1. Calculate the wavelength (in centimeters) of each sound wave by dividing the speed of sound in air (343 m/s at 20°C) by the frequency and multiplying by 100.
2. Make the following graphs: air column length versus frequency and wavelength versus frequency. On both graphs, plot the frequency on the *x*-axis.
3. Describe the trend between the length of the air column and the frequency of the tuning fork.
4. How are the pitches you heard related to the wavelengths of the sounds?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Skills Practice Lab

The Energy of Sound

In the chapter entitled "The Nature of Sound," you learned about various properties and interactions of sound. In this lab, you will perform several activities that will demonstrate that the properties and interactions of sound all depend on one thing—the energy carried by sound waves.

MATERIALS

- cup, plastic, small, filled with water
- eraser, pink, rubber
- rubber band
- string, 50 cm
- tuning forks, same frequency (2), different frequency (1)

SAFETY

Part A: Sound Vibrations

Procedure

1. Lightly strike a tuning fork with the eraser. Slowly place the prongs of the tuning fork in the plastic cup of water. Record your observations.

Part B: Resonance

Procedure

1. Strike a tuning fork with the eraser. Quickly pick up a second tuning fork in your other hand, and hold it about 30 cm from the first tuning fork.
2. Place the first tuning fork against your leg to stop the tuning fork's vibration. Listen closely to the second tuning fork. Record your observations, including the frequencies of the two tuning forks.
3. Repeat steps 1 and 2, using the remaining tuning fork as the second tuning fork.

Part C: Interference

Procedure

1. Use the two tuning forks that have the same frequency, and place a rubber band tightly over the prongs near the base of one tuning fork, as shown at right. Strike both tuning forks against the eraser. Hold the stems of the tuning forks against a table, 3 cm to 5 cm apart. If you cannot hear any differences, move the rubber band up or down the prongs. Strike again. Record your observations.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Part D: The Doppler Effect

Procedure

1. Your teacher will tie the piece of string securely to the base of one tuning fork. Your teacher will then strike the tuning fork and carefully swing the tuning fork in a circle overhead. Record your observations.

Analyze the Results

1. How do your observations demonstrate that sound waves are carried through vibrations?
2. Explain why you can hear a sound from the second tuning fork when the frequencies of the tuning forks used are the same.
3. When using tuning forks of different frequencies, would you expect to hear a sound from the second tuning fork if you strike the first tuning fork harder? Explain your reasoning.
4. Did you notice the sound changing back and forth between loud and soft? A steady pattern like this one is called a *beat frequency.* Explain this changing pattern of loudness and softness in terms of interference (both constructive and destructive).
5. Did the tuning fork make a different sound when your teacher was swinging it than when he or she was holding it? If yes, explain why.
6. Is the actual pitch of the tuning fork changing when it is swinging? Explain.

Draw Conclusions

7. Explain how your observations from each part of this lab verify that sound waves carry energy from one point to another through a vibrating medium.
8. Particularly loud thunder can cause the windows of your room to rattle. How is this evidence that sound waves carry energy?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Using Scientific Methods

Skills Practice Lab

What Color of Light Is Best for Green Plants?

Plants grow well outdoors under natural sunlight. However, some plants are grown indoors under artificial light. A variety of colored lights are available for helping plants grow indoors. In this experiment, you'll test several colors of light to discover which color best meets the energy needs of green plants.

MATERIALS

- bean seedlings
- colored lights, supplied by your teacher
- marker, felt-tip
- paper towels
- Petri dishes with covers
- tape, masking
- water

SAFETY

Ask a Question

1. Which color of light is best for growing green plants?

Form a Hypothesis

2. Write a hypothesis that answers the question above. Explain your reasoning.

Test the Hypothesis

3. Use the masking tape and marker to label the side of each Petri dish with your name and the type of light under which you will place the dish.
4. Place a moist paper towel in each Petri dish. Place 5 seedlings on top of the paper towel. Cover each dish.
5. Record your observations of the seedlings, such as length, color, and number of leaves.
6. Place each dish under the appropriate light.
7. Observe the Petri dishes every day for at least 5 days. Record your observations.

Analyze the Results

1. Based on your results, which color of light is best for growing green plants? Which color of light is worst?

Draw Conclusions

2. Remember that the color of an opaque object (such as a plant) is determined by the colors the object reflects. Use this information to explain your answer to question 1 above.
3. Would a purple light be good for growing purple plants? Explain.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Skills Practice Lab

Which Color Is Hottest?

Will a navy blue hat or a white hat keep your head warmer in cool weather? Colored objects absorb energy, which can make the objects warmer. How much energy is absorbed depends on the object's color. In this experiment, you will test several colors under a bright light to determine which colors absorb the most energy.

MATERIALS

- light source
- paper, colored, squares
- paper, graph
- paper towels
- pencils or pens, colored
- tape, transparent
- thermometer
- water, room-temperature

SAFETY

Procedure

1. Copy the table below. Be sure to have one column for each color of paper you use and enough rows to end at 3 min.

Data Collection Table

Time (s)	White	Red	Blue	Black
0				
15				
30				
45				
etc.				

DO NOT WRITE IN BOOK

2. Tape a piece of colored paper around the bottom of a thermometer, and hold it under the light source. Record the temperature every 15 s for 3 min.
3. Cool the thermometer by removing the piece of paper and placing the thermometer in the cup of room-temperature water. After 1 min, remove the thermometer, and dry it with a paper towel.
4. Repeat steps 2 and 3 with each color, making sure to hold the thermometer at the same distance from the light source.

Analyze the Results

1. Prepare a graph of temperature (*y*-axis) versus time (*x*-axis). Using a different colored pencil or pen for each set of data, plot all data on one graph.
2. Rank the colors you used in order from hottest to coolest.

Draw Conclusions

3. Compare the colors, based on the amount of energy each absorbs.
4. In this experiment, a white light was used. How would your results be different if you used a red light? Explain.
5. Use the relationship between color and energy absorbed to explain why different colors of clothing are used for different seasons.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Model-Making Lab

Adaptation: It's a Way of Life

Since the beginning of life on Earth, species have had special characteristics called *adaptations* that have helped them survive changes in environmental conditions. Changes in a species' environment include climate changes, habitat destruction, or the extinction of prey. These things can cause a species to die out unless the species has a characteristic that helps it survive. For example, a species of bird may have an adaptation for eating sunflower seeds and ants. If the ant population dies out, the bird can still eat seeds and can therefore survive.

In this activity, you will explore several adaptations and design an organism with adaptations you choose. Then, you will describe how these adaptations help the organism survive.

MATERIALS

- arts-and-crafts materials, various
- markers, colored
- magazines for cutouts
- poster board
- scissors

SAFETY

Procedure

1. Study the chart below. Choose one adaptation from each column. For example, an organism might be a scavenger that burrows underground and has spikes on its tail!

Adaptations		
Diet	**Type of transportation**	**Special adaptation**
carnivore	flies	uses sensors to detect heat
herbivore	glides through the air	is active only at night and has excellent night vision
omnivore	burrows underground	changes colors to match its surroundings
scavenger	runs fast	has armor
decomposer	swims	has horns
	hops	can withstand extreme temperature changes
	walks	secretes a terrible and sickening scent
	climbs	has poison glands
	floats	has specialized front teeth
	slithers	has tail spikes
		stores oxygen in its cells so it does not have to breathe continuously
		one of your own invention

Copyright © by Holt, Rinehart and Winston. All rights reserved.

2. Design an organism that has the three adaptations you have chosen. Use poster board, colored markers, picture cutouts, or craft materials of your choosing to create your organism.
3. Write a caption on your poster describing your organism. Describe its appearance, its habitat, its niche, and the way its adaptations help it survive. Give your organism a two-part "scientific" name that is based on its characteristics.
4. Display your creation in your classroom. Share with classmates how you chose the adaptations for your organism.

Analyze the Results

1. What does your imaginary organism eat?
2. In what environment or habitat would your organism be most likely to survive—in the desert, tropical rain forest, plains, icecaps, mountains, or ocean? Explain your answer.
3. Is your creature a mammal, a reptile, an amphibian, a bird, or a fish? What modern organism (on Earth today) or ancient organism (extinct) is your imaginary organism most like? Explain the similarities between the two organisms. Do some research outside the lab, if necessary, to find out about a real organism that may be similar to your imaginary organism.

Draw Conclusions

4. If there were a sudden climate change, such as daily downpours of rain in a desert, would your imaginary organism survive? What adaptations for surviving such a change does it have?

Applying Your Data

Call or write to an agency such as the U.S. Fish and Wildlife Service to get a list of endangered species in your area. Choose an organism on that list. Describe the organism's niche and any special adaptations it has that help it survive. Find out why it is endangered and what is being done to protect it.

Examine the illustration of the animal at right. Based on its physical characteristics, describe its habitat and niche. Is this a real animal?

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Model-Making Lab

A Passel o' Pioneers

Succession is the natural process of the introduction and development of living things in an area. The area could be one that has never supported life before and has no soil, such as a recently cooled lava flow from a volcano. In an area where there is no soil, the process is called *primary succession.* In an area where soil already exists, such as an abandoned field or a forest after a fire, the process is called *secondary succession.*

In this investigation, you will build a model of secondary succession using natural soil.

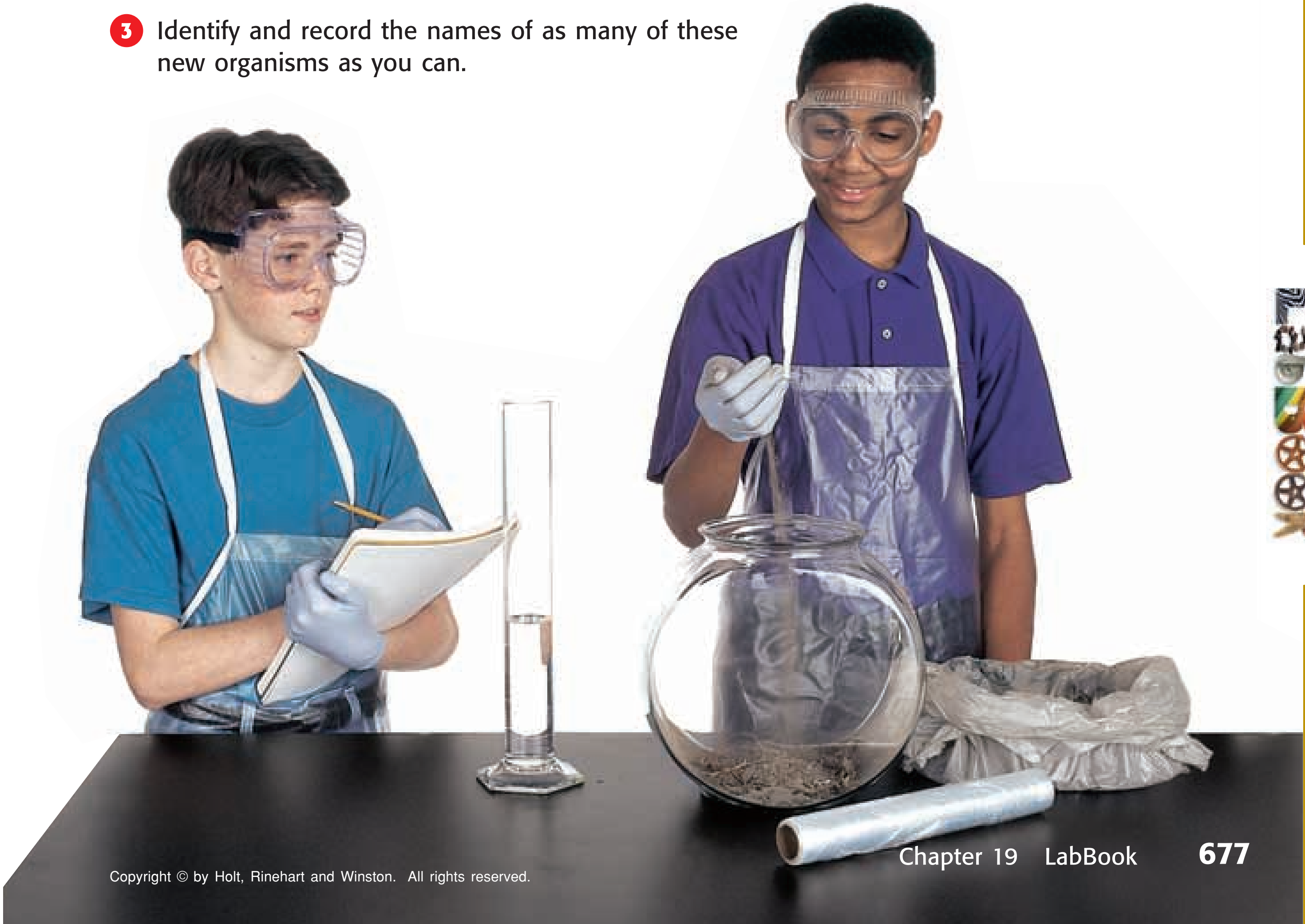
MATERIALS

- balance
- graduated cylinder, 250 mL
- large fishbowl
- plastic wrap
- protective gloves
- soil from home or schoolyard, 500 g
- water, 250 mL

SAFETY

Procedure

1. Place the natural soil you brought from home or the schoolyard into the fishbowl, and dampen the soil with 250 mL of water. Cover the top of the fishbowl with plastic wrap, and place the fishbowl in a sunny window.
   Caution: Do not touch your face, eyes, or mouth during this activity. Wash your hands thoroughly when you are finished.
2. For 2 weeks, observe the fishbowl for any new growth. Describe and draw any new organisms you observe. Record these and all other observations.
3. Identify and record the names of as many of these new organisms as you can.



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Analyze the Results

1. What kinds of plants sprouted in your model of secondary succession? Were they tree seedlings, grasses, or weeds?
2. Were the plants that sprouted in the fishbowl unusual or common for your area?

Draw Conclusions

3. Explain how the plants that grew in your model of secondary succession can be called pioneer species.

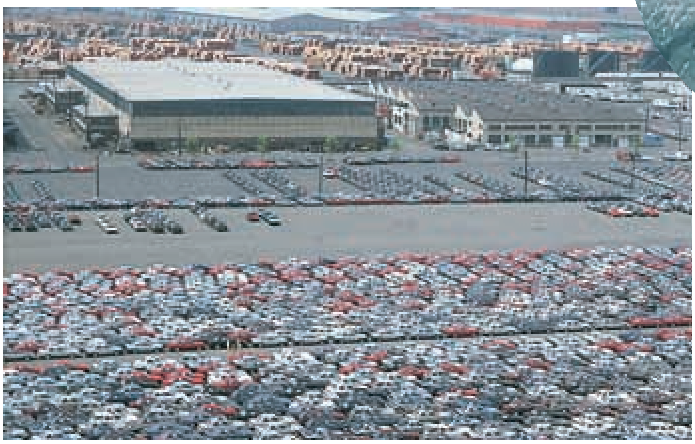
Applying Your Data

Examine each of the photographs on this page. Determine whether each area, if abandoned forever, would undergo primary or secondary succession. You may decide that an area will not undergo succession at all. Explain your reasoning.

Bulldozed land

Eutrophic pond

Mount St. Helens volcano



Shipping port parking lot

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Skills Practice Lab

Deciding About Environmental Issues

You make hundreds of decisions every day. Some of them are complicated, but many of them are very simple, such as what to wear or what to eat for lunch. Deciding what to do about an environmental issue can be very difficult. There are many different factors that must be considered. How will a certain solution affect people's lives? How much will it cost? Is it ethically right?

In this activity, you will analyze an issue in four steps to help you make a decision about it. Find out about environmental issues that are being discussed in your area. Examine newspapers, magazines, and other publications to find out what the issues are. Choose one local issue to evaluate. For example, you could evaluate whether the city should spend the money to provide recycling bins and special trucks for picking up recyclable trash.

MATERIALS

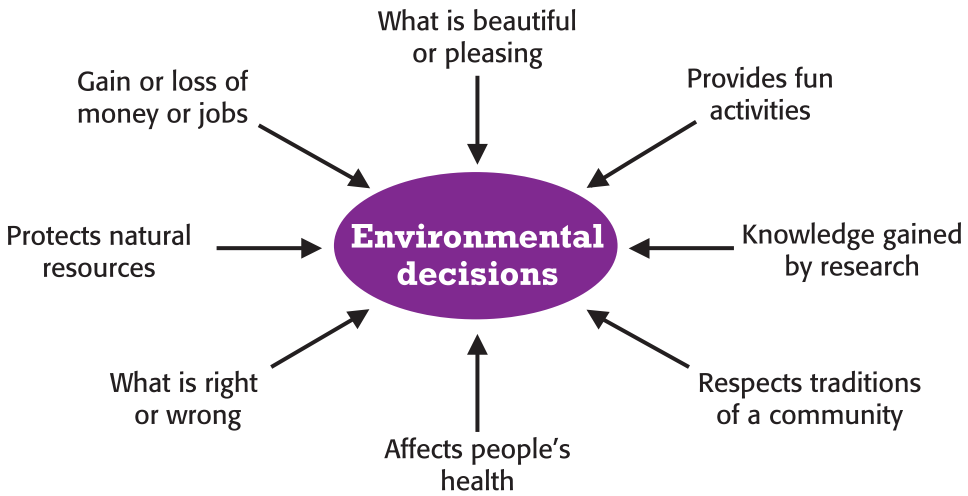
- newspapers, magazines, and other publications containing information about environmental issues

A Four-Step Decision-Making Model

Gather Information
↓
Consider Values
↓
Explore Consequences
↓
Make a Decision

Procedure

1. Write a statement about an environmental issue.
2. Read about your issue in several publications. On a separate sheet of paper, summarize important facts.
3. The values of an issue are the things that you consider important. Examine the diagram below. Several values are given. Which values do you think apply most to the environmental issue you are considering? Are there other values that you believe will help you make a decision about the issue? Consider at least four values in making your decision.



Copyright © by Holt, Rinehart and Winston. All rights reserved.

4. Consequences are the things that result from a certain course of action. Create a table similar to the one below. Use your table to organize your thoughts about consequences related to your environmental issue. List your values at the top. Fill in each space with the consequences for each value.

Consequences Table

Consequences	Values			
Positive short-term consequences				
Negative short-term consequences				
Positive long-term consequences				
Negative long-term consequences				

DO NOT WRITE IN BOOK

5. Thoroughly consider all of the consequences you have recorded in your table. Evaluate how important each consequence is. Make a decision about what course of action you would choose on the issue.

Analyze the Results

1. In your evaluation, did you consider short-term consequences or long-term consequences to be more important? Why?

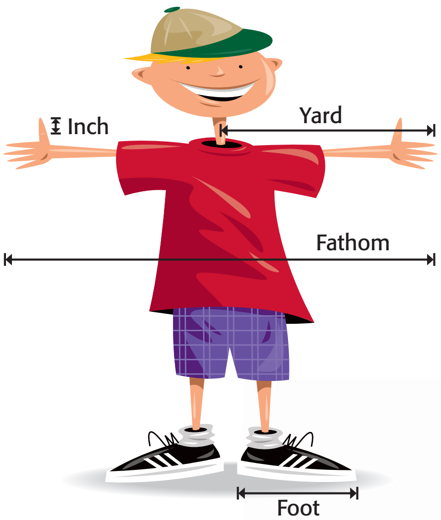
2. Which value or values had the greatest influence on your final decision? Explain your reasoning.

Communicating Your Data

Compare your table with your classmates' tables. Did you all make the same decision about a similar issue? If not, form teams, and organize a formal classroom debate of a specific environmental issue.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Contents



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Reading Check Answers

Chapter 1 Science in Our World

Section 1

Page 4: the knowledge gained by observing the natural world

Page 6: Recycling paper protects forests and saves fuel and chemicals from being used to make paper from trees.

Page 9: Science educators work in schools, zoos, aquariums, and national parks.

Section 2

Page 11: Scientific methods help scientists get reliable answers.

Page 13: A variable is the only factor that is changed in a controlled experiment.

Page 14: Scientists can make tables or graphs to organize their data.

Page 16: Scientists can write reports for scientific journals, give talks on their results, or put their results on the Internet.

Section 3

Page 19: Three kinds of models are physical, mathematical, and conceptual models.

Page 20: Models can represent both very large and very small objects at a size that you can easily see.

Section 4

Page 22: a tube that has lenses at each end, a stage, and a light

Page 25: Area measures how much surface area an object has.

Page 27: When you don't understand a safety symbol, you should ask your teacher for help.

Chapter 2 Minerals of the Earth's Crust

Section 1

Page 41: An element is a pure substance that cannot be broken down into simpler substances by ordinary chemical means. A compound is a substance made of two or more elements that have been chemically bonded.

Page 42: Answers may vary. Silicate minerals contain a combination of silicon and oxygen; nonsilicate minerals do not contain a combination of silicon and oxygen.

Section 2

Page 45: A mineral's streak is not affected by air or water, but a mineral's color may be affected by air or water.

Page 46: Scratch the mineral with a series of 10 reference minerals. If the reference mineral scratches the unidentified mineral, the reference mineral is harder than the unidentified mineral.

Section 3

Page 51: Surface mining is used to remove mineral deposits that are at or near the Earth's surface. Subsurface mining is used to remove mineral deposits that are too deep to be removed by surface mining.

Page 53: Sample answer: Gemstones are nonmetallic minerals that are valued for their beauty and rarity rather than for their usefulness.

Chapter 3 Rocks: Mineral Mixtures

Section 1

Page 64: Types of rocks that have been used by humans to construct buildings include granite, limestone, marble, sandstone, and slate.

Page 68: Rock within the Earth is affected by temperature and pressure.

Page 69: The minerals that a rock contains determine a rock's composition.

Page 70: Fine-grained rocks are made of small grains, such as silt or clay particles. Medium-grained rocks are made of medium-sized grains, such as sand. Coarse-grained rocks are made of large grains, such as pebbles.

Section 2

Page 73: Felsic rocks are light-colored igneous rocks rich in aluminum, potassium, silicon, and sodium. Mafic rocks are dark-colored igneous rocks rich in calcium, iron, and magnesium.

Page 75: New sea floor forms when lava that flows from fissures on the ocean floor cools and hardens.

Section 3

Page 77: Halite forms when sodium and chlorine ions in shallow water bodies become so concentrated that halite crystallizes from solution.

Page 79: Ripple marks are the marks left by wind and water waves on lakes, seas, rivers, and sand dunes.

Section 4

Page 81: Regional metamorphism occurs when pressure builds up in rock that is buried deep below other rock formations or when large pieces of the Earth's crust collide. The increased pressure can cause thousands of square miles of rock to become deformed and chemically changed.

Page 82: An index mineral is a metamorphic mineral that forms only at certain temperatures and pressures and therefore can be used by scientists to estimate the temperature, pressure, and depth at which a rock undergoes metamorphosis.

Page 85: Deformation causes metamorphic structures, such as folds.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Chapter 4 Plate Tectonics

Section 1

Page 97: The crust is the thin, outermost layer of the Earth. It is 5 km to 100 km thick and is mainly made up of the elements oxygen, silicon, and aluminum. The mantle is the layer between the crust and core. It is 2,900 km thick, is denser than the crust, and contains most of the Earth's mass. The core is the Earth's innermost layer. The core has a radius of 3,430 km and is made mostly of iron.

Page 98: The five physical layers of the Earth are the lithosphere, asthenosphere, mesosphere, outer core, and inner core.

Page 101: Although continental lithosphere is less dense than oceanic lithosphere is, continental lithosphere has a greater mass because of its greater thickness and will displace more asthenosphere than oceanic lithosphere.

Page 102: Answers may vary. A seismic wave traveling through a solid will go faster than a seismic wave traveling through a liquid.

Section 2

Page 104: Similar fossils were found on landmasses that are very far apart. The best explanation for this phenomenon is that the landmasses were once joined.

Page 107: The molten rock at mid-ocean ridges contains tiny grains of magnetic minerals. The minerals align with the Earth's magnetic field before the rock cools and hardens. When the Earth's magnetic field reverses, the orientation of the mineral grains in the rocks will also change.

Section 3

Page 109: A transform boundary forms when two tectonic plates slide past each other horizontally.

Page 110: The circulation of thermal energy causes changes in density in the asthenosphere. As rock is heated, it expands, becomes less dense, and rises. As rock cools, it contracts, becomes denser, and sinks.

Section 4

Page 112: Compression can cause rocks to be pushed into mountain ranges as tectonic plates collide at convergent boundaries. Tension can pull rocks apart as tectonic plates separate at divergent boundaries.

Page 114: In a normal fault, the hanging wall moves down. In a reverse fault, the hanging wall moves up.

Page 116: Folded mountains form when rock layers are squeezed together and pushed upward.

Chapter 5 Earthquakes

Section 1

Page 131: During elastic rebound, rock releases energy. Some of this energy travels as seismic waves that cause earthquakes.

Page 133: Earthquake zones are usually located along tectonic plate boundaries.

Page 135: Surface waves travel more slowly than body waves but are more destructive.

Section 2

Page 137: Seismologists determine an earthquake's start time by comparing seismograms and noting differences in arrival times of P and S waves.

Page 138: Each time the magnitude increases by 1 unit, the amount of ground motion increases by 10 times.

Section 3

Page 141: With a decrease of one unit in earthquake magnitude, the number of earthquakes occurring annually increases by about 10 times.

Page 142: Retrofitting is the process of making older structures more earthquake resistant.

Page 144: You should crouch or lie face down under a table or desk.

Chapter 6 Volcanoes

Section 1

Page 157: Nonexplosive eruptions are common, and they feature relatively calm flows of lava. Explosive eruptions are less common and produce large, explosive clouds of ash and gases.

Page 158: Because silica-rich magma has a high viscosity, it tends to trap gases and plug volcanic vents. This causes pressure to build up and can result in an explosive eruption.

Page 160: Volcanic bombs are large blobs of magma that harden in the air. Lapilli are small pieces of magma that harden in the air. Volcanic blocks are pieces of solid rock erupted from a volcano. Ash forms when gases in stiff magma expand rapidly and the walls of the gas bubbles shatter into tiny glasslike slivers.

Section 2

Page 162: Eruptions release large quantities of ash and gases, which can block sunlight and cause global temperatures to drop.

Page 164: Calderas form when a magma chamber partially empties and the roof overlying the chamber collapses.

Section 3

Page 167: Volcanic activity is common at tectonic plate boundaries because magma tends to form at plate boundaries.

Page 169: When a tectonic plate subducts, it becomes hotter and releases water. The water lowers the melting point of the rock above the plate, causing magma to form.

Page 170: According to one theory, a rising body of magma, called a mantle plume, causes a chain of volcanoes to form on a moving tectonic plate. According to another theory, a chain of volcanoes forms along cracks in the Earth's crust.

Chapter 7 Weathering and Soil Formation

Section 1

Page 185: Wind, water, and gravity can cause abrasion.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Page 186: Answers may vary. Sample answer: ants, worms, mice, coyotes, and rabbits.

Page 189: Oxidation occurs when oxygen combines with an element to form an oxide.

Section 2

Page 191: As the surface area increases, the rate of weathering also increases.

Page 192: Warm, humid climates have higher rates of weathering because oxidation happens faster when temperatures are higher and when water is present.

Page 193: Mountains weather faster because they are exposed to more wind, rain, and ice, which are agents of weathering.

Section 3

Page 194: Soil is formed from parent rock, organic material, water, and air.

Page 197: Colors that indicate soil is fertile are black, dark brown, red, and yellow.

Page 198: Heavy rains leach precious nutrients into deeper layers of soil, resulting in a very thin layer of topsoil.

Page 200: Temperate climates have the most productive soil.

Section 4

Page 202: Soil provides nutrients to plants, houses for animals, and stores water.

Page 204: The roots of plants anchor topsoil and keep the topsoil from eroding away.

Page 206: They restore important nutrients to the soil and provide cover to prevent erosion.

Chapter 8 Agents of Erosion and Deposition

Section 1

Page 219: The amount of energy released from breaking waves causes rock to break down, eventually forming sand.

Page 221: Large waves are more capable of moving large rocks on a shoreline because they have more energy than normal waves do.

Page 222: Beach material is material deposited by waves.

Section 2

Page 225: Deflation hollows form in areas where there is little vegetation.

Page 227: Dunes move in the direction of strong winds.

Section 3

Page 228: Alpine glaciers form in mountainous areas.

Page 233: A till deposit is made up of unsorted material, while stratified drift is made up of sorted material.

Section 4

Page 235: A slump is the result of a landslide in which a block of material moves downslope over a curved surface.

Page 236: A lahar is caused by the eruption of an ice-covered volcano, which melts ice and causes a hot mudflow.

Chapter 9 Earth, Sun, and Moon

Section 1

Page 251: Kepler's third law of motion states that the farther away from the sun a planet is, the longer the planet takes to orbit the sun.

Page 252: Newton's law of universal gravitation states that the force of gravity depends on the product of the masses of the objects divided by the square of the distance between the objects.

Section 2

Page 255: The seasons are caused by the tilt of the Earth's axis.

Page 256: An equinox describes the time in which the sun is directly above the equator.

Section 3

Page 259: Waxing means "growing" and waning means "shrinking."

Page 260: During a solar eclipse, the moon comes between the Earth and the sun and the shadow of the moon falls on part of the Earth.

Section 4

Page 262: The gravity of the moon pulls on every particle of the Earth.

Page 264: A tidal range is the difference between levels of ocean water at high tide and low tide.

Chapter 10 Formation of the Solar System

Section 1

Page 276: 9.46 trillion kilometers

Page 279: Irregular galaxies are galaxies that don't fit into any other class. Their shape is irregular.

Page 280: A globular cluster is a tight group of up to 1 million stars that looks like a ball. An open cluster is a group of closely grouped stars that are usually located along the spiral disk of a galaxy.

Section 2

Page 282: The solar nebula is the cloud of gas and dust that formed our solar system.

Page 284: Jupiter, Saturn, Uranus, and Neptune

Section 3

Page 287: Energy from gravity is not enough to power the sun, because if all of the sun's gravitational energy were released, the sun would last for only 45 million years.

Page 289: The nuclei of hydrogen atoms repel each other because they are positively charged and like charges repel each other.

Page 290: Sunspots are cooler, dark spots on the sun. Sunspots occur because when activity slows down in the convective zone, areas of the photosphere become cooler.

Section 4

Page 293: During Earth's early formation, planetesimals collided with the Earth. The energy of their motion heated the planet.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Page 294: Scientists think that the Earth's early atmosphere was a steamy mixture of carbon dioxide and water vapor.

Page 296: When photosynthetic organisms appeared on Earth, they released oxygen into the Earth's atmosphere. Over several million years, more and more oxygen was added to the atmosphere, which helped form Earth's current atmosphere.

Chapter 11 A Family Of Planets

Section 1

Page 309: Light travels about 300,000 km/s.

Page 311: Jupiter, Saturn, Uranus, Neptune, and Pluto are in the outer solar system.

Section 2

Page 313: Radar technology was used to map the surface of Venus.

Page 314: The Earth Science Enterprise is a program designed to Earth as a global system made of smaller systems.

Page 316: Mars' crust is chemically different from Earth's crust, so the Martian crust does not move. As a result, volcanoes build up in the same spots on Mars.

Section 3

Page 319: Saturn's rings are made of icy particles ranging in size from a few centimeters to several meters wide.

Page 321: Neptune's interior releases energy to its outer layers, which creates belts of clouds in Neptune's atmosphere.

Section 4

Page 325: The rate of cratering can help scientists determine the age of a body's surface.

Page 326: Because Titan's atmosphere is similar to the atmosphere on Earth before life evolved, scientists can study Titan's atmosphere to learn

Page 327: Pluto is eclipsed by Charon every 120 years.

Section 5

Page 329: Comets come from the Oort cloud and the Kuiper belt.

Page 331: The major types of meteorites are stony, metallic, and stony-iron meteorites.

Page 332: Large objects strike Earth every few thousand years.

Chapter 12 Exploring Space

Section 1

Page 344: Tsiolkovsky helped develop rocket theory. Goddard developed the first rockets.

Page 346: Rockets carry oxygen so that their fuel can be burned.

Section 2

Page 349: Answers may vary. LEO is much closer to the Earth than GEO.

Page 351: Information from one location is transmitted to a communications satellite. The satellite then sends the information to another location on Earth.

Page 353: Satellites in the EOS program are designed to work together so that many different types of data can be integrated.

Section 3

Page 355: The Magellan mission showed that, in many ways, the surface of Venus is similar to the surface of Earth.

Page 356: The Mars Pathfinder mission found evidence suggesting that water once flowed across the surface of Mars.

Page 358: The mission of the Stardust probe is to gather samples from a comet's tail and return them to Earth.

Section 4

Page 361: the orbiter, the liquid-fuel tank, and the solid-fuel booster rockets

Page 363: The Russians are supplying a service module, docking modules, life-support and research modules, and transportation to and from the station. The Americans are providing lab modules, the supporting frame, solar panels, living quarters, and a biomedical laboratory.

Page 365: Space-age spinoffs are technologies that were developed for the space program but are now used in everyday life.

Page 366: Tires that are stronger than normal tires are an example of a transportation spinoff.

Chapter 13 Energy and Energy Resources

Section 1

Page 380: Energy is the ability to do work.

Page 383: kinetic energy and potential energy

Page 385: Sound energy consists of vibrations carried through the air.

Page 386: Nuclear energy comes from changes in the nucleus of an atom.

Section 2

Page 389: A roller coaster has the greatest potential energy at the top of the highest hill (usually the first hill) and the greatest kinetic energy at the bottom of the highest hill.

Page 390: Plants get their energy from the sun.

Page 392: Machines can change the size or direction of the input force.

Section 3

Page 395: Conservation of energy is considered a scientific law because no exception to it has ever been observed.

Page 396: Perpetual motion is impossible because energy conversions always result in the production of waste thermal energy.

Section 4

Page 398: Fossil fuels are nonrenewable resources because they are used up more quickly than they are replaced.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Page 400: Nuclear energy comes from radioactive elements that give off energy during nuclear fission.

Page 402: Geothermal energy comes from the thermal energy given off by underground areas of hot rock.

Chapter 14 Temperature and Heat

Section 1

Page 415: Temperature is a measure of the average kinetic energy of the particles of a substance.

Page 416: Thermal expansion makes thermometers work.

Page 418: Expansion joints on a bridge allow the bridge to undergo thermal expansion without breaking.

Page 420: In general, nonmetal materials, such as glass and ceramics, do not conduct heat very well.

Section 2

Page 423: If two objects at different temperatures come into contact, thermal energy will be transferred from the higher-temperature object to the lower-temperature object until both objects are at the same temperature.

Page 425: Two objects that are at the same temperature can feel as though they are at different temperatures if one object is a better thermal conductor than the other is. The better conductor will feel colder because it will draw thermal energy away from your hand faster.

Page 427: The greenhouse effect is the trapping of thermal energy from the sun in Earth's atmosphere.

Page 428: Specific heat, mass, and the change in temperature are needed to calculate heat.

Chapter 15 The Energy of Waves

Section 1

Page 442: All waves are disturbances that transmit energy.

Page 444: Electromagnetic waves do not require a medium.

Page 446: A sound wave is a longitudinal wave.

Section 2

Page 449: Shaking the rope faster makes the wavelength shorter; shaking the rope more slowly makes the wavelength longer.

Page 450: 3 Hz

Section 3

Page 453: It refracts.

Page 455: Constructive interference occurs when the crests of one wave overlap the crests of another wave.

Page 456: A standing wave results from a wave that is reflected between two fixed points. Interference from the wave and reflected waves cause certain points to remain at rest and certain points to remain at a large amplitude.

Chapter 16 The Nature of Sound

Section 1

Page 469: Sound waves consist of longitudinal waves carried through a medium.

Page 470: Sound needs a medium in order to travel.

Page 472: Tinnitus is caused by long-term exposure to loud sounds.

Section 2

Page 475: Frequency is the number of crests or troughs made in a given time.

Page 477: The amplitude of a sound increases as the energy of the vibrations that caused the sound increases.

Page 478: An oscilloscope turns sounds into electrical signals and graphs the signals.

Section 3

Page 481: Echolocation helps some animals find food.

Page 482: Sound wave interference can be either constructive or destructive.

Page 484: A standing wave is a pattern of vibration that looks like a wave that is standing still.

Section 4

Page 487: Musical instruments differ in the part of the instrument that vibrates and in the way that the vibrations are made.

Page 489: Music consists of sound waves that have regular patterns, and noise consists of a random mix of frequencies.

Chapter 17 The Nature of Light

Section 1

Page 501: Electric fields can be found around every charged object.

Page 502: The speed of light is about 880,000 times faster than the speed of sound.

Section 2

Page 504: The law of reflection states that the angle of incidence equals the angle of reflection.

Page 505: Sample answer: Four light sources are a television screen, a fluorescent light in the classroom, a light bulb, and the tail of a firefly.

Page 506: You can see things outside of a beam of light because light is scattered outside of the beam.

Page 509: The amount that a wave diffracts depends on the wavelength of the wave and the size of the barrier or opening.

Page 510: Constructive interference is interference in which the resulting wave has a greater amplitude than the original waves had.

Section 3

Page 513: Sample answer: Two translucent objects are a frosted window and wax paper.

Page 514: When white light shines on a colored opaque object, some of the colors of light are absorbed and some are reflected.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Page 516: A pigment is a material that gives color to a substance by absorbing some colors of light and reflecting others.

Section 4

Page 519: Nearsightedness happens when a person's eye is too long. Farsightedness happens when a person's eye is too short.

Page 520: The three kinds of cones are red, blue, and green.

Chapter 18 Interactions of Living Things

Section 1

Page 537: The biosphere is the part of Earth where life exists.

Section 2

Page 539: Organisms that eat other organisms are called *consumers*.

Page 541: An energy pyramid is a diagram that shows an ecosystem's loss of energy.

Page 542: Other animals in Yellowstone National Park were affected by the disappearance of the gray wolf because the food web was interrupted. The animals that would normally be prey for the gray wolf were more plentiful. These larger populations ate more vegetation.

Section 3

Page 545: The main ways that organisms affect each other are through competition, predator and prey relationships, symbiotic relationships, and coevolution.

Page 547: Camouflage helps an organism blend in with its surroundings because of its coloring. It is harder for a predator to find a camouflaged prey.

Page 548: In a mutualistic relationship, both organisms benefit from the relationship.

Page 550: Flowers need to attract pollinators to help the flowers reproduce with other members of their species.

Chapter 19 Cycling of Matter

Section 1

Page 563: Without water, there would be no life on Earth.

Section 2

Page 566: Plants grew back, and the area is recovering.

Page 568: Primary succession happens in an area where organisms did not previously exist; secondary succession happens where organisms already exist.

Section 3

Page 570: Chlorophyll reflects more wavelengths of green light than wavelengths of other colors of light. So, most plants look green.

Page 573: Sample answer: Photosynthesis provides the oxygen that organisms need for cellular respiration. Photosynthetic organisms form the base of nearly all food chains on Earth.

Section 4

Page 574: water, light, favorable temperatures, nutrients, and soil

Page 576: Animals depend on light for the growth of plants. Light also enables many animal species to see during the day. Light can also affect when animals mate to migrate.

Page 579: Plants rely on soil as a medium in which to grow. Plants obtain mineral nutrients and water from soil.

Chapter 20 Environmental Problems and Solutions

Section 1

Page 590: Sample answer: Hazardous waste is waste that can catch fire, wear through metal, explode, or make people sick.

Page 593: As more people move around, more natural resources are needed. Eventually, the resources may become depleted. Also, using some of these resources contributes to pollution.

Page 594: Point-source pollution is pollution that comes from one place. Nonpoint-source pollution is pollution that comes from many places.

Section 2

Page 596: reduce, reuse, and recycle

Page 598: Sample answer: Water is reclaimed with plants or filter-feeding animals. Then, it can be used to water crops, parks, lawns, and golf courses.

Page 601: Sample answer: The EPA is a government organization that helps protect the environment.

Chapter 21 The Evolution of Living Things

Section 1

Page 614: if they mate with each other and produce more of the same type of organism

Page 616: by their estimated ages and physical similarities

Page 618: a four-legged land mammal

Page 620: that they have common ancestry

Section 2

Page 623: 965 km (600 mi) west of Ecuador

Page 625: that Earth had been formed by natural processes over a long period of time

Page 626: *On the Origin of Species by Means of Natural Selection*

Section 3

Page 629: because they often produce many offspring and have short generation times

Page 630: Sample answer: A newly formed canyon, mountain range, or lake could divide the members of a population.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Study Skills

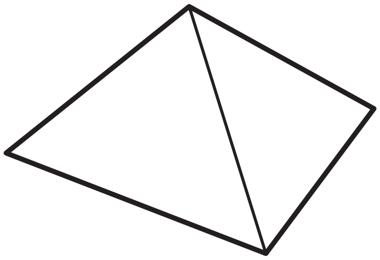
FoldNote Instructions

Have you ever tried to study for a test or quiz but didn't know where to start? Or have you read a chapter and found that you can remember only a few ideas? Well, FoldNotes are a fun and exciting way to help you learn and remember the ideas you encounter as you learn science!

FoldNotes are tools that you can use to organize concepts. By focusing on a few main concepts, FoldNotes help you learn and remember how the concepts fit together. They can help you see the "big picture." Below you will find instructions for building 10 different FoldNotes.

Pyramid

1. Place a sheet of paper in front of you. Fold the lower left-hand corner of the paper diagonally to the opposite edge of the paper.
2. Cut off the tab of paper created by the fold (at the top).
3. Open the paper so that it is a square. Fold the lower right-hand corner of the paper diagonally to the opposite corner to form a triangle.
4. Open the paper. The creases of the two folds will have created an X.
5. Using scissors, cut along one of the creases. Start from any corner, and stop at the center point to create two flaps. Use tape or glue to attach one of the flaps on top of the other flap.



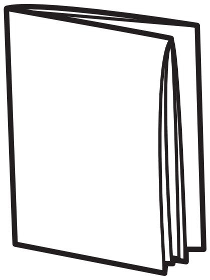
Double Door

1. Fold a sheet of paper in half from the top to the bottom. Then, unfold the paper.
2. Fold the top and bottom edges of the paper to the crease.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

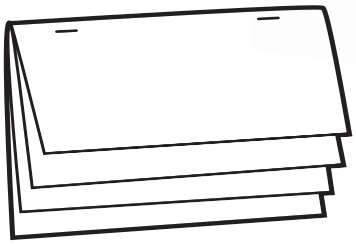
Booklet

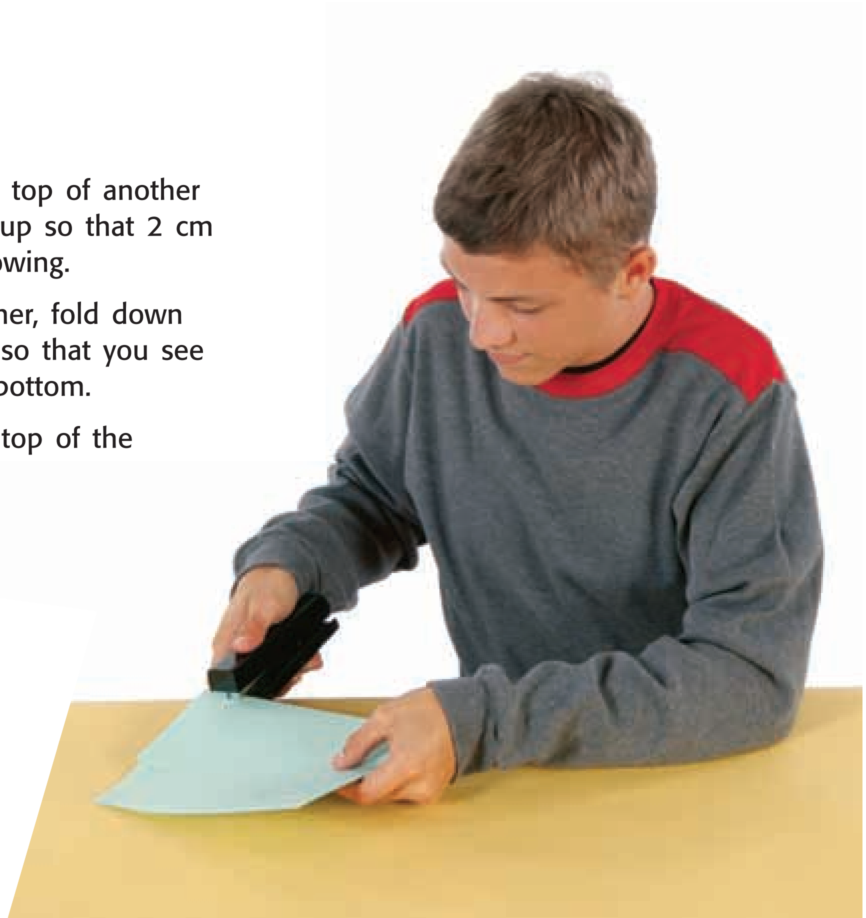
1. Fold a sheet of paper in half from left to right. Then, unfold the paper.
2. Fold the sheet of paper in half again from the top to the bottom. Then, unfold the paper.
3. Refold the sheet of paper in half from left to right.
4. Fold the top and bottom edges to the center crease.
5. Completely unfold the paper.
6. Refold the paper from top to bottom.
7. Using scissors, cut a slit along the center crease of the sheet from the folded edge to the creases made in step 4. Do not cut the entire sheet in half.
8. Fold the sheet of paper in half from left to right. While holding the bottom and top edges of the paper, push the bottom and top edges together so that the center collapses at the center slit. Fold the four flaps to form a four-page book.



Layered Book

1. Lay one sheet of paper on top of another sheet. Slide the top sheet up so that 2 cm of the bottom sheet is showing.
2. Hold the two sheets together, fold down the top of the two sheets so that you see four 2 cm tabs along the bottom.
3. Using a stapler, staple the top of the FoldNote.





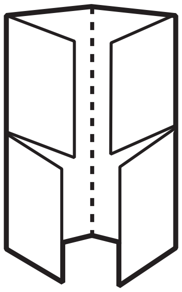
Copyright © by Holt, Rinehart and Winston. All rights reserved.

Key-Term Fold

1. Fold a sheet of lined notebook paper in half from left to right.
2. Using scissors, cut along every third line from the right edge of the paper to the center fold to make tabs.

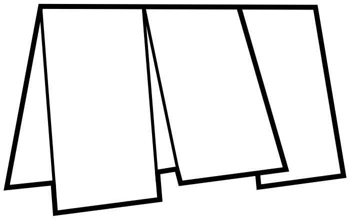
Four-Corner Fold

1. Fold a sheet of paper in half from left to right. Then, unfold the paper.
2. Fold each side of the paper to the crease in the center of the paper.
3. Fold the paper in half from the top to the bottom. Then, unfold the paper.
4. Using scissors, cut the top flap creases made in step 3 to form four flaps.



Three-Panel Flip Chart

1. Fold a piece of paper in half from the top to the bottom.
2. Fold the paper in thirds from side to side. Then, unfold the paper so that you can see the three sections.
3. From the top of the paper, cut along each of the vertical fold lines to the fold in the middle of the paper. You will now have three flaps.



Appendix

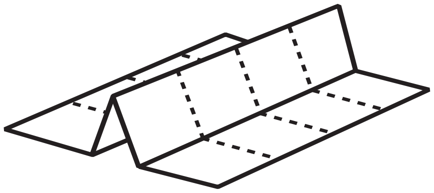
Copyright © by Holt, Rinehart and Winston. All rights reserved.

Table Fold

1. Fold a piece of paper in half from the top to the bottom. Then, fold the paper in half again.

2. Fold the paper in thirds from side to side.

3. Unfold the paper completely. Carefully trace the fold lines by using a pen or pencil.

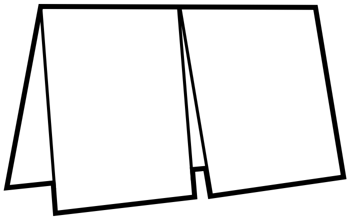


Two-Panel Flip Chart

1. Fold a piece of paper in half from the top to the bottom.

2. Fold the paper in half from side to side. Then, unfold the paper so that you can see the two sections.

3. From the top of the paper, cut along the vertical fold line to the fold in the middle of the paper. You will now have two flaps.

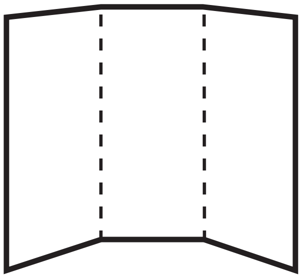


Tri-Fold

1. Fold a piece a paper in thirds from the top to the bottom.

2. Unfold the paper so that you can see the three sections. Then, turn the paper sideways so that the three sections form vertical columns.

3. Trace the fold lines by using a pen or pencil. Label the columns “Know,” “Want,” and “Learn.”



Copyright © by Holt, Rinehart and Winston. All rights reserved.

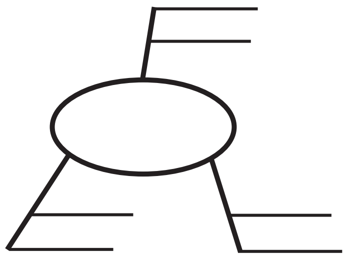
Graphic Organizer Instructions

Have you ever wished that you could "draw out" the many concepts you learn in your science class? Sometimes, being able to *see* how concepts are related really helps you remember what you've learned. Graphic Organizers do just that! They give you a way to draw or map out concepts.

All you need to make a Graphic Organizer is a piece of paper and a pencil. Below you will find instructions for four different Graphic Organizers designed to help you organize the concepts you'll learn in this book.

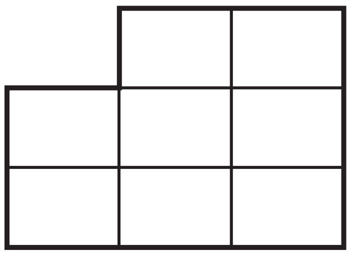
Spider Map

1. Draw a diagram like the one shown. In the circle, write the main topic.
2. From the circle, draw legs to represent different categories of the main topic. You can have as many categories as you want.
3. From the category legs, draw horizontal lines. As you read the chapter, write details about each category on the horizontal lines.



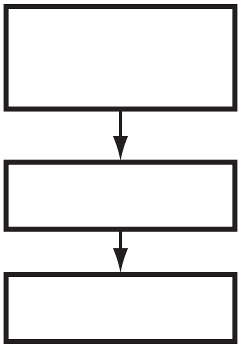
Comparison Table

1. Draw a chart like the one shown. Your chart can have as many columns and rows as you want.
2. In the top row, write the topics that you want to compare.
3. In the left column, write characteristics of the topics that you want to compare. As you read the chapter, fill in the characteristics for each topic in the appropriate boxes.



Copyright © by Holt, Rinehart and Winston. All rights reserved.

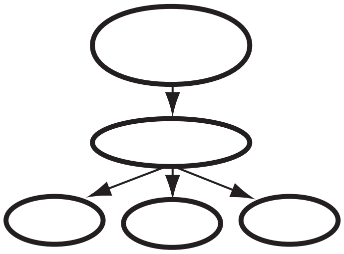
Chain-of-Events-Chart



1. Draw a box. In the box, write the first step of a process or the first event of a timeline.
2. Under the box, draw another box, and use an arrow to connect the two boxes. In the second box, write the next step of the process or the next event in the timeline.
3. Continue adding boxes until the process or timeline is finished.

Concept Map

1. Draw a circle in the center of a piece of paper. Write the main idea of the chapter in the center of the circle.
2. From the circle, draw other circles. In those circles, write characteristics of the main idea. Draw arrows from the center circle to the circles that contain the characteristics.
3. From each circle that contains a characteristic, draw other circles. In those circles, write specific details about the characteristic. Draw arrows from each circle that contains a characteristic to the circles that contain specific details. You may draw as many circles as you want.



Appendix

Copyright © by Holt, Rinehart and Winston. All rights reserved.

SI Measurement

The International System of Units, or SI, is the standard system of measurement used by many scientists. Using the same standards of measurement makes it easier for scientists to communicate with one another.

SI works by combining prefixes and base units. Each base unit can be used with different prefixes to define smaller and larger quantities. The table below lists common SI prefixes.

SI Prefixes			
Prefix	**Symbol**	**Factor**	**Example**
kilo-	k	1,000	kilogram, 1 kg = 1,000 g
hecto-	h	100	hectoliter, 1 hL = 100 L
deka-	da	10	dekameter, 1 dam = 10 m
		1	meter, liter, gram
deci-	d	0.1	decigram, 1 dg = 0.1 g
centi-	c	0.01	centimeter, 1 cm = 0.01 m
milli-	m	0.001	milliliter, 1 mL = 0.001 L
micro-	μ	0.000 001	micrometer, 1 μm = 0.000 001 m

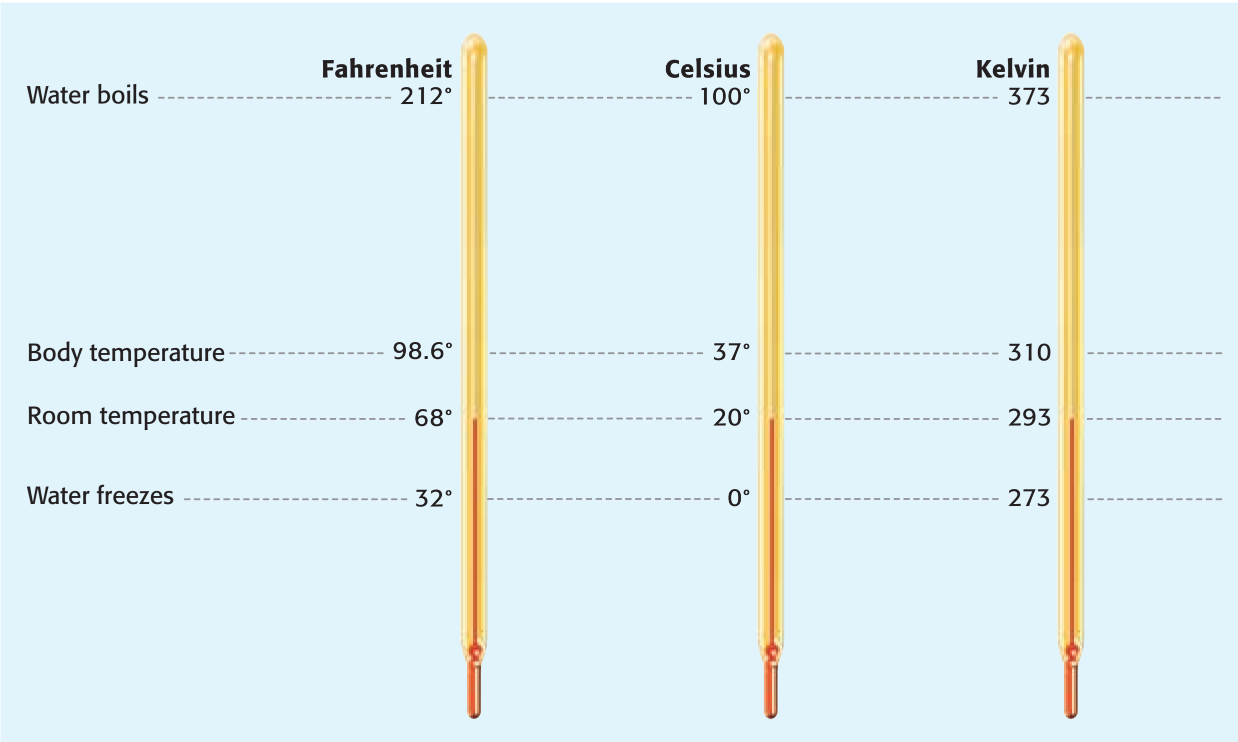
SI Conversion Table		
SI units	**From SI to English**	**From English to SI**
Length		
kilometer (km) = 1,000 m	1 km = 0.621 mi	1 mi = 1.609 km
meter (m) = 100 cm	1 m = 3.281 ft	1 ft = 0.305 m
centimeter (cm) = 0.01 m	1 cm = 0.394 in.	1 in. = 2.540 cm
millimeter (mm) = 0.001 m	1 mm = 0.039 in.	
micrometer (μm) = 0.000 001 m		
nanometer (nm) = 0.000 000 001 m		
Area		
square kilometer (km^2) = 100 hectares	1 km^2 = 0.386 mi^2	1 mi^2 = 2.590 km^2
hectare (ha) = 10,000 m^2	1 ha = 2.471 acres	1 acre = 0.405 ha
square meter (m^2) = 10,000 cm^2	1 m^2 = 10.764 ft^2	1 ft^2 = 0.093 m^2
square centimeter (cm^2) = 100 mm^2	1 cm^2 = 0.155 $in.^2$	1 $in.^2$ = 6.452 cm^2
Volume		
liter (L) = 1,000 mL = 1 dm^3	1 L = 1.057 fl qt	1 fl qt = 0.946 L
milliliter (mL) = 0.001 L = 1 cm^3	1 mL = 0.034 fl oz	1 fl oz = 29.574 mL
microliter (μL) = 0.000 001 L		
Mass		
kilogram (kg) = 1,000 g	1 kg = 2.205 lb	1 lb = 0.454 kg
gram (g) = 1,000 mg	1 g = 0.035 oz	1 oz = 28.350 g
milligram (mg) = 0.001 g		
microgram (μg) = 0.000 001 g		

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Temperature Scales

Temperature can be expressed by using three different scales: Fahrenheit, Celsius, and Kelvin. The SI unit for temperature is the kelvin (K). Although 0 K is much colder than 0°C, a change of 1 K is equal to a change of 1°C.

Three Temperature Scales



Temperature Conversions Table

To convert	Use this equation:	Example
Celsius to Fahrenheit °C → °F	$°F = \left(\frac{9}{5} \times °C\right) + 32$	Convert 45°C to °F. $°F = \left(\frac{9}{5} \times 45°C\right) + 32 = 113°F$
Fahrenheit to Celsius °F → °C	$°C = \frac{5}{9} \times (°F - 32)$	Convert 68°F to °C. $°C = \frac{5}{9} \times (68°F - 32) = 20°C$
Celsius to Kelvin °C → K	$K = °C + 273$	Convert 45°C to K. $K = 45°C + 273 = 318\ K$
Kelvin to Celsius K → °C	$°C = K - 273$	Convert 32 K to °C. $°C = 32K - 273 = -241°C$

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Measuring Skills

Using a Graduated Cylinder

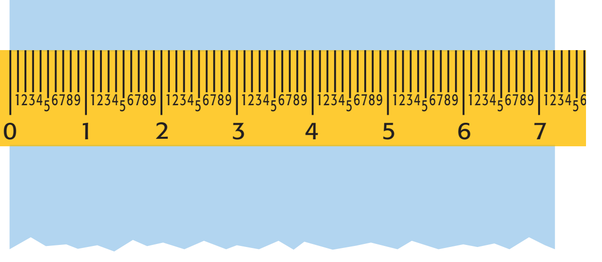
When using a graduated cylinder to measure volume, keep the following procedures in mind:

1. Place the cylinder on a flat, level surface before measuring liquid.
2. Move your head so that your eye is level with the surface of the liquid.
3. Read the mark closest to the liquid level. On glass graduated cylinders, read the mark closest to the center of the curve in the liquid's surface.

Using a Meterstick or Metric Ruler

When using a meterstick or metric ruler to measure length, keep the following procedures in mind:

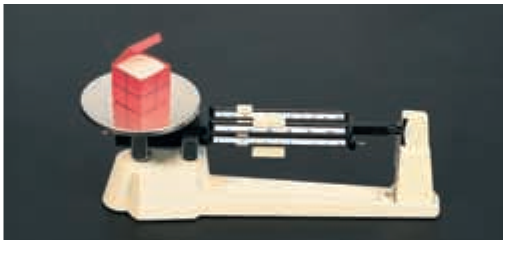
1. Place the ruler firmly against the object that you are measuring.
2. Align one edge of the object exactly with the 0 end of the ruler.
3. Look at the other edge of the object to see which of the marks on the ruler is closest to that edge. (Note: Each small slash between the centimeters represents a millimeter, which is one-tenth of a centimeter.)



Using a Triple-Beam Balance

When using a triple-beam balance to measure mass, keep the following procedures in mind:

1. Make sure the balance is on a level surface.
2. Place all of the countermasses at 0. Adjust the balancing knob until the pointer rests at 0.
3. Place the object you wish to measure on the pan. **Caution:** Do not place hot objects or chemicals directly on the balance pan.
4. Move the largest countermass along the beam to the right until it is at the last notch that does not tip the balance. Follow the same procedure with the next-largest countermass. Then, move the smallest countermass until the pointer rests at 0.
5. Add the readings from the three beams together to determine the mass of the object.
6. When determining the mass of crystals or powders, first find the mass of a piece of filter paper. Then, add the crystals or powder to the paper, and remeasure. The actual mass of the crystals or powder is the total mass minus the mass of the paper. When finding the mass of liquids, first find the mass of the empty container. Then, find the combined mass of the liquid and container. The mass of the liquid is the total mass minus the mass of the container.



Appendix

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Scientific Methods

The ways in which scientists answer questions and solve problems are called **scientific methods.** The same steps are often used by scientists as they look for answers. However, there is more than one way to use these steps. Scientists may use all of the steps or just some of the steps during an investigation. They may even repeat some of the steps. The goal of using scientific methods is to come up with reliable answers and solutions.

Six Steps of Scientific Methods

1 Ask a Question

Good questions come from careful **observations.** You make observations by using your senses to gather information. Sometimes, you may use instruments, such as microscopes and telescopes, to extend the range of your senses. As you observe the natural world, you will discover that you have many more questions than answers. These questions drive investigations.

Questions beginning with *what, why, how,* and *when* are important in focusing an investigation. Here is an example of a question that could lead to an investigation.

Question: How does acid rain affect plant growth?

2 Form a Hypothesis

After you ask a question, you need to form a **hypothesis.** A hypothesis is a clear statement of what you expect the answer to your question to be. Your hypothesis will represent your best "educated guess" based on what you have observed and what you already know. A good hypothesis is testable. Otherwise, the investigation can go no further. Here is a hypothesis based on the question, "How does acid rain affect plant growth?"

Hypothesis: Acid rain slows plant growth.

The hypothesis can lead to predictions. A prediction is what you think the outcome of your experiment or data collection will be. Predictions are usually stated in an if-then format. Here is a sample prediction for the hypothesis that acid rain slows plant growth.

Prediction: If a plant is watered with only acid rain (which has a pH of 4), then the plant will grow at half its normal rate.

3 Test the Hypothesis

After you have formed a hypothesis and made a prediction, your hypothesis should be tested. One way to test a hypothesis is with a controlled experiment. A **controlled experiment** tests only one factor at a time. In an experiment to test the effect of acid rain on plant growth, the **control group** would be watered with normal rain water. The **experimental group** would be watered with acid rain. All of the plants should receive the same amount of sunlight and water each day. The air temperature should be the same for all groups. However, the acidity of the water will be a variable. In fact, any factor that is different from one group to another is a **variable.** If your hypothesis is correct, then the acidity of the water and plant growth are *dependant variables.* The amount a plant grows is dependent on the acidity of the water. However, the amount of water each plant receives and the amount of sunlight each plant receives are *independent variables.* Either of these factors could change without affecting the other factor.

Sometimes, the nature of an investigation makes a controlled experiment impossible. For example, the Earth's core is surrounded by thousands of meters of rock. Under such circumstances, a hypothesis may be tested by making detailed observations.

4 Analyze the Results

After you have completed your experiments, made your observations, and collected your data, you must analyze all the information you have gathered. Tables and graphs are often used in this step to organize the data.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

5 Draw Conclusions

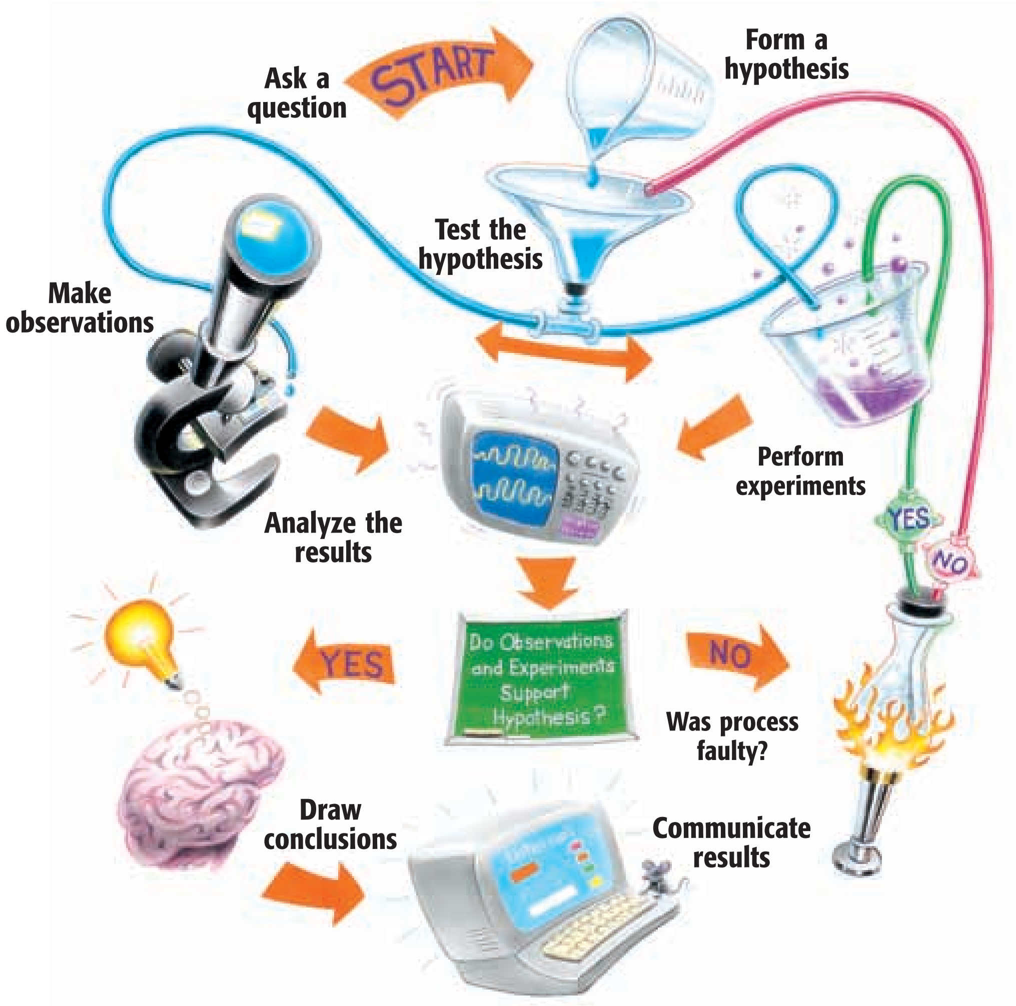
After analyzing your data, you can determine if your results support your hypothesis. If your hypothesis is supported, you (or others) might want to repeat the observations or experiments to verify your results. If your hypothesis is not supported by the data, you may have to check your procedure for errors. You may even have to reject your hypothesis and make a new one. If you cannot draw a conclusion from your results, you may have to try the investigation again or carry out further observations or experiments.

6 Communicate Results

After any scientific investigation, you should report your results. By preparing a written or oral report, you let others know what you have learned. They may repeat your investigation to see if they get the same results. Your report may even lead to another question and then to another investigation.

Scientific Methods in Action

Scientific methods contain loops in which several steps may be repeated over and over again. In some cases, certain steps are unnecessary. Thus, there is not a "straight line" of steps. For example, sometimes scientists find that testing one hypothesis raises new questions and new hypotheses to be tested. And sometimes, testing the hypothesis leads directly to a conclusion. Furthermore, the steps in scientific methods are not always used in the same order. Follow the steps in the diagram, and see how many different directions scientific methods can take you.



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Making Charts and Graphs

Pie Charts

A pie chart shows how each group of data relates to all of the data. Each part of the circle forming the chart represents a category of the data. The entire circle represents all of the data. For example, a biologist studying a hardwood forest in Wisconsin found that there were five different types of trees. The data table at right summarizes the biologist's findings.

Wisconsin Hardwood Trees

Type of tree	Number found
Oak	600
Maple	750
Beech	300
Birch	1,200
Hickory	150
Total	3,000

How to Make a Pie Chart

1. To make a pie chart of these data, first find the percentage of each type of tree. Divide the number of trees of each type by the total number of trees, and multiply by 100.

$$\frac{600 \text{ oak}}{3{,}000 \text{ trees}} \times 100 = 20\%$$

$$\frac{750 \text{ maple}}{3{,}000 \text{ trees}} \times 100 = 25\%$$

$$\frac{300 \text{ beech}}{3{,}000 \text{ trees}} \times 100 = 10\%$$

$$\frac{1{,}200 \text{ birch}}{3{,}000 \text{ trees}} \times 100 = 40\%$$

$$\frac{150 \text{ hickory}}{3{,}000 \text{ trees}} \times 100 = 5\%$$

2. Now, determine the size of the wedges that make up the pie chart. Multiply each percentage by 360°. Remember that a circle contains 360°.

$20\% \times 360° = 72°$ $\quad 25\% \times 360° = 90°$

$10\% \times 360° = 36°$ $\quad 40\% \times 360° = 144°$

$5\% \times 360° = 18°$

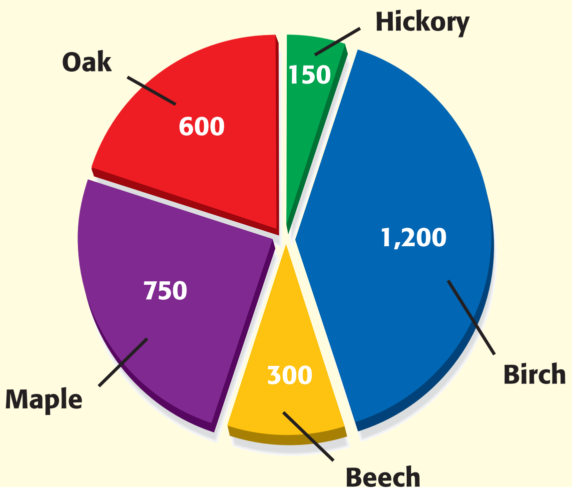
3. Check that the sum of the percentages is 100 and the sum of the degrees is 360.

$20\% + 25\% + 10\% + 40\% + 5\% = 100\%$

$72° + 90° + 36° + 144° + 18° = 360°$

4. Use a compass to draw a circle and mark the center of the circle.
5. Then, use a protractor to draw angles of 72°, 90°, 36°, 144°, and 18° in the circle.
6. Finally, label each part of the chart, and choose an appropriate title.

A Community of Wisconsin Hardwood Trees



Appendix

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Line Graphs

Line graphs are most often used to demonstrate continuous change. For example, Mr. Smith's students analyzed the population records for their hometown, Appleton, between 1900 and 2000. Examine the data at right.

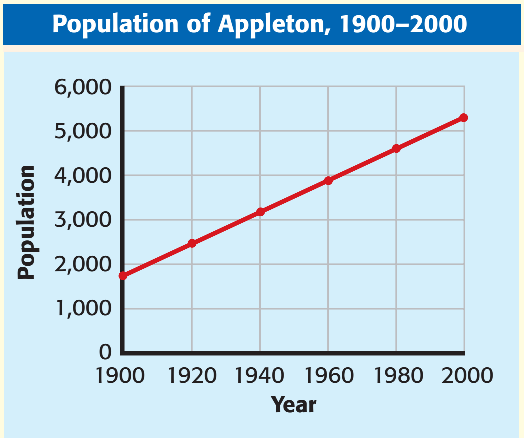
Because the year and the population change, they are the *variables*. The population is determined by, or dependent on, the year. Therefore, the population is called the **dependent variable,** and the year is called the **independent variable.** Each set of data is called a **data pair.** To prepare a line graph, you must first organize data pairs into a table like the one at right.

Population of Appleton, 1900–2000

Year	Population
1900	1,800
1920	2,500
1940	3,200
1960	3,900
1980	4,600
2000	5,300

How to Make a Line Graph

1. Place the independent variable along the horizontal (x) axis. Place the dependent variable along the vertical (y) axis.
2. Label the x-axis "Year" and the y-axis "Population." Look at your largest and smallest values for the population. For the y-axis, determine a scale that will provide enough space to show these values. You must use the same scale for the entire length of the axis. Next, find an appropriate scale for the x-axis.
3. Choose reasonable starting points for each axis.
4. Plot the data pairs as accurately as possible.
5. Choose a title that accurately represents the data.



How to Determine Slope

Slope is the ratio of the change in the y-value to the change in the x-value, or "rise over run."

1. Choose two points on the line graph. For example, the population of Appleton in 2000 was 5,300 people. Therefore, you can define point a as (2000, 5,300). In 1900, the population was 1,800 people. You can define point b as (1900, 1,800).
2. Find the change in the y-value. (y at point a) − (y at point b) = 5,300 people − 1,800 people = 3,500 people
3. Find the change in the x-value. (x at point a) − (x at point b) = 2000 − 1900 = 100 years
4. Calculate the slope of the graph by dividing the change in y by the change in x.

$$slope = \frac{change\ in\ y}{change\ in\ x}$$

$$slope = \frac{3{,}500 \text{ people}}{100 \text{ years}}$$

$$slope = 35 \text{ people per year}$$

In this example, the population in Appleton increased by a fixed amount each year. The graph of these data is a straight line. Therefore, the relationship is **linear.** When the graph of a set of data is not a straight line, the relationship is **nonlinear.**

Appendix

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Using Algebra to Determine Slope

The equation in step 4 may also be arranged to be

$$y = kx$$

where y represents the change in the y-value, k represents the slope, and x represents the change in the x-value.

$$slope = \frac{change\ in\ y}{change\ in\ x}$$

$$k = \frac{y}{x}$$

$$k \times x = \frac{y \times x}{x}$$

$$kx = y$$

Bar Graphs

Bar graphs are used to demonstrate change that is not continuous. These graphs can be used to indicate trends when the data cover a long period of time. A meteorologist gathered the precipitation data shown here for Hartford, Connecticut, for April 1–15, 1996, and used a bar graph to represent the data.

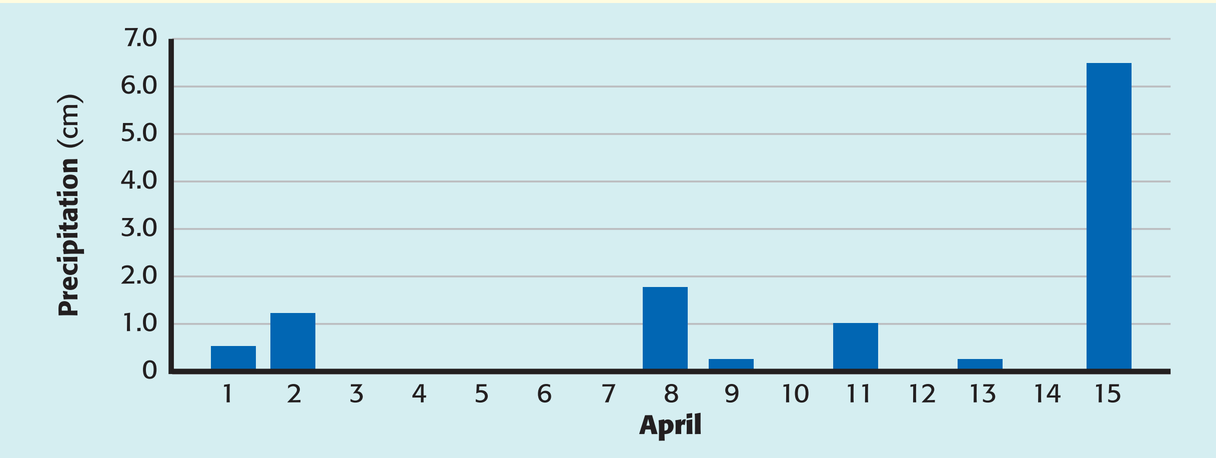
Precipitation in Hartford, Connecticut April 1–15, 1996

Date	Precipitation (cm)	Date	Precipitation (cm)
April 1	0.5	April 9	0.25
April 2	1.25	April 10	0.0
April 3	0.0	April 11	1.0
April 4	0.0	April 12	0.0
April 5	0.0	April 13	0.25
April 6	0.0	April 14	0.0
April 7	0.0	April 15	6.50
April 8	1.75		

How to Make a Bar Graph

1. Use an appropriate scale and a reasonable starting point for each axis.
2. Label the axes, and plot the data.
3. Choose a title that accurately represents the data.

Precipitation in Hartford, Connecticut, April 1–15, 1996



Appendix

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Math Refresher

Science requires an understanding of many math concepts. The following pages will help you review some important math skills.

Averages

An **average,** or **mean,** simplifies a set of numbers into a single number that *approximates* the value of the set.

Example: Find the average of the following set of numbers: 5, 4, 7, and 8.

Step 1: Find the sum.

$$5 + 4 + 7 + 8 = 24$$

Step 2: Divide the sum by the number of numbers in your set. Because there are four numbers in this example, divide the sum by 4.

$$\frac{24}{4} = 6$$

The average, or mean, is **6.**

Ratios

A **ratio** is a comparison between numbers, and it is usually written as a fraction.

Example: Find the ratio of thermometers to students if you have 36 thermometers and 48 students in your class.

Step 1: Make the ratio.

$$\frac{36 \text{ thermometers}}{48 \text{ students}}$$

Step 2: Reduce the fraction to its simplest form.

$$\frac{36}{48} = \frac{36 \div 12}{48 \div 12} = \frac{3}{4}$$

The ratio of thermometers to students is **3 to 4,** or $\frac{3}{4}$. The ratio may also be written in the form 3:4.

Proportions

A **proportion** is an equation that states that two ratios are equal.

$$\frac{3}{1} = \frac{12}{4}$$

To solve a proportion, first multiply across the equal sign. This is called *cross-multiplication*. If you know three of the quantities in a proportion, you can use cross-multiplication to find the fourth.

Example: Imagine that you are making a scale model of the solar system for your science project. The diameter of Jupiter is 11.2 times the diameter of the Earth. If you are using a plastic-foam ball that has a diameter of 2 cm to represent the Earth, what must the diameter of the ball representing Jupiter be?

$$\frac{11.2}{1} = \frac{x}{2 \text{ cm}}$$

Step 1: Cross-multiply.

$$\frac{11.2}{1} \times \frac{x}{2}$$

$$11.2 \times 2 = x \times 1$$

Step 2: Multiply.

$$22.4 = x \times 1$$

Step 3: Isolate the variable by dividing both sides by 1.

$$x = \frac{22.4}{1}$$

$$x = 22.4 \text{ cm}$$

You will need to use a ball that has a diameter of **22.4** cm to represent Jupiter.

Appendix

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Percentages

A **percentage** is a ratio of a given number to 100.

Example: What is 85% of 40?

Step 1: Rewrite the percentage by moving the decimal point two places to the left.

0.85

Step 2: Multiply the decimal by the number that you are calculating the percentage of.

$0.85 \times 40 = 34$

85% of 40 is **34.**

Decimals

To **add** or **subtract decimals,** line up the digits vertically so that the decimal points line up. Then, add or subtract the columns from right to left. Carry or borrow numbers as necessary.

Example: Add the following numbers: 3.1415 and 2.96.

Step 1: Line up the digits vertically so that the decimal points line up.

$$\begin{array}{r} 3.1415 \\ +\ 2.96 \\ \hline \end{array}$$

Step 2: Add the columns from right to left, and carry when necessary.

$$\begin{array}{r} {\scriptstyle 1\ 1} \\ 3.1415 \\ +\ 2.96 \\ \hline 6.1015 \end{array}$$

The sum is **6.1015.**

Fractions

Numbers tell you how many; **fractions** tell you *how much of a whole*.

Example: Your class has 24 plants. Your teacher instructs you to put 5 plants in a shady spot. What fraction of the plants in your class will you put in a shady spot?

Step 1: In the denominator, write the total number of parts in the whole.

$$\frac{?}{24}$$

Step 2: In the numerator, write the number of parts of the whole that are being considered.

$$\frac{5}{24}$$

So, $\mathbf{\frac{5}{24}}$ of the plants will be in the shade.

Reducing Fractions

It is usually best to express a fraction in its simplest form. Expressing a fraction in its simplest form is called *reducing* a fraction.

Example: Reduce the fraction $\frac{30}{45}$ to its simplest form.

Step 1: Find the largest whole number that will divide evenly into both the numerator and denominator. This number is called the *greatest common factor* (GCF).

Factors of the numerator 30:

1, 2, 3, 5, 6, 10, **15,** 30

Factors of the denominator 45:

1, 3, 5, 9, **15,** 45

Step 2: Divide both the numerator and the denominator by the GCF, which in this case is 15.

$$\frac{30}{45} = \frac{30 \div 15}{45 \div 15} = \frac{2}{3}$$

Thus, $\frac{30}{45}$ reduced to its simplest form is $\mathbf{\frac{2}{3}}$.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Adding and Subtracting Fractions

To **add** or **subtract fractions** that have the **same denominator,** simply add or subtract the numerators.

Examples:

$$\frac{3}{5} + \frac{1}{5} = ? \text{ and } \frac{3}{4} - \frac{1}{4} = ?$$

Step 1: Add or subtract the numerators.

$$\frac{3}{5} + \frac{1}{5} = \frac{4}{} \text{ and } \frac{3}{4} - \frac{1}{4} = \frac{2}{}$$

Step 2: Write the sum or difference over the denominator.

$$\frac{3}{5} + \frac{1}{5} = \frac{4}{5} \text{ and } \frac{3}{4} - \frac{1}{4} = \frac{2}{4}$$

Step 3: If necessary, reduce the fraction to its simplest form.

$\mathbf{\frac{4}{5}}$ cannot be reduced, and $\frac{2}{4} = \mathbf{\frac{1}{2}}$.

To **add** or **subtract fractions** that have **different denominators,** first find the least common denominator (LCD).

Examples:

$$\frac{1}{2} + \frac{1}{6} = ? \text{ and } \frac{3}{4} - \frac{2}{3} = ?$$

Step 1: Write the equivalent fractions that have a common denominator.

$$\frac{3}{6} + \frac{1}{6} = ? \text{ and } \frac{9}{12} - \frac{8}{12} = ?$$

Step 2: Add or subtract the fractions.

$$\frac{3}{6} + \frac{1}{6} = \frac{4}{6} \text{ and } \frac{9}{12} - \frac{8}{12} = \frac{1}{12}$$

Step 3: If necessary, reduce the fraction to its simplest form.

The fraction $\frac{4}{6} = \mathbf{\frac{2}{3}}$, and $\mathbf{\frac{1}{12}}$ cannot be reduced.

Multiplying Fractions

To **multiply fractions,** multiply the numerators and the denominators together, and then reduce the fraction to its simplest form.

Example:

$$\frac{5}{9} \times \frac{7}{10} = ?$$

Step 1: Multiply the numerators and denominators.

$$\frac{5}{9} \times \frac{7}{10} = \frac{5 \times 7}{9 \times 10} = \frac{35}{90}$$

Step 2: Reduce the fraction.

$$\frac{35}{90} = \frac{35 \div 5}{90 \div 5} = \mathbf{\frac{7}{18}}$$

Dividing Fractions

To **divide fractions,** first rewrite the divisor (the number you divide by) upside down. This number is called the *reciprocal* of the divisor. Then multiply and reduce if necessary.

Example:

$$\frac{5}{8} \div \frac{3}{2} = ?$$

Step 1: Rewrite the divisor as its reciprocal.

$$\frac{3}{2} \rightarrow \frac{2}{3}$$

Step 2: Multiply the fractions.

$$\frac{5}{8} \times \frac{2}{3} = \frac{5 \times 2}{8 \times 3} = \frac{10}{24}$$

Step 3: Reduce the fraction.

$$\frac{10}{24} = \frac{10 \div 2}{24 \div 2} = \mathbf{\frac{5}{12}}$$

Appendix

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Scientific Notation

Scientific notation is a short way of representing very large and very small numbers without writing all of the place-holding zeros.

Example: Write 653,000,000 in scientific notation.

Step 1: Write the number without the place-holding zeros.

653

Step 2: Place the decimal point after the first digit.

6.53

Step 3: Find the exponent by counting the number of places that you moved the decimal point.

6.53000000

The decimal point was moved eight places to the left. Therefore, the exponent of 10 is positive 8. If you had moved the decimal point to the right, the exponent would be negative.

Step 4: Write the number in scientific notation.

$\mathbf{6.53 \times 10^8}$

Area

Area is the number of square units needed to cover the surface of an object.

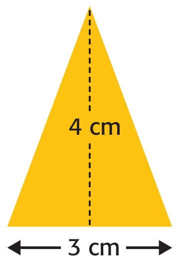
Formulas:

area of a square = *side* × *side*

area of a rectangle = *length* × *width*

area of a triangle = $\frac{1}{2}$ × *base* × *height*

Examples: Find the areas.

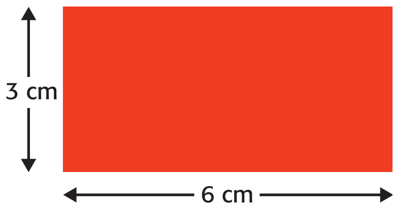


Triangle

$area = \frac{1}{2} \times base \times height$

$area = \frac{1}{2} \times 3\text{ cm} \times 4\text{ cm}$

$area = \mathbf{6\ cm^2}$

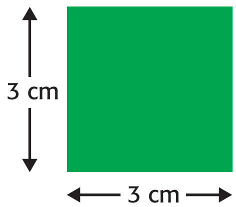


Rectangle

area = *length* × *width*

area = 6 cm × 3 cm

area = $\mathbf{18\ cm^2}$



Square

area = *side* × *side*

area = 3 cm × 3 cm

area = $\mathbf{9\ cm^2}$

Volume

Volume is the amount of space that something occupies.

Formulas:

volume of a cube = *side* × *side* × *side*

volume of a prism = *area of base* × *height*

Examples:

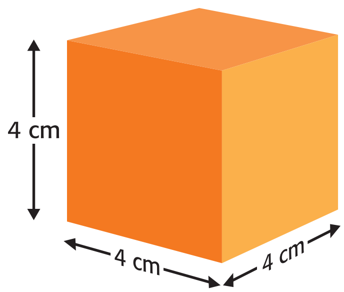
Find the volume of the solids.

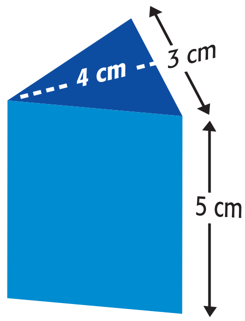
Cube

volume = *side* × *side* × *side*

volume = 4 cm × 4 cm × 4 cm

volume = $\mathbf{64\ cm^3}$





Prism

volume = *area of base* × *height*

volume = (*area of triangle*) × *height*

volume = $(\frac{1}{2} \times 3\text{ cm} \times 4\text{ cm}) \times 5\text{ cm}$

volume = $6\text{ cm}^2 \times 5\text{ cm}$

volume = $\mathbf{30\ cm^3}$

Appendix

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Physical Science Laws and Equations

Law of Conservation of Energy

The law of conservation of energy states that energy can be neither created nor destroyed.

The total amount of energy in a closed system is always the same. Energy can be changed from one form to another, but all of the different forms of energy in a system always add up to the same total amount of energy no matter how many energy conversions occur.

Law of Universal Gravitation

The law of universal gravitation states that all objects in the universe attract each other by a force called *gravity.* The size of the force depends on the masses of the objects and the distance between objects.

The first part of the law explains why a bowling ball is much harder to lift than a table-tennis ball. Because the bowling ball has a much larger mass than the table-tennis ball does, the amount of gravity between the Earth and the bowling ball is greater than the amount of gravity between the Earth and the table-tennis ball.

The second part of the law explains why a satellite can remain in orbit around the Earth. The satellite is carefully placed at a distance great enough to prevent the Earth's gravity from immediately pulling the satellite down but small enough to prevent the satellite from completely escaping the Earth's gravity and wandering off into space.

Newton's Laws of Motion

Newton's first law of motion states that an object at rest remains at rest and an object in motion remains in motion at constant speed and in a straight line unless acted on by an unbalanced force.

The first part of the law explains why a football will remain on a tee until it is kicked off or until a gust of wind blows it off.

The second part of the law explains why a bike rider will continue moving forward after the bike comes to an abrupt stop. Gravity and the friction of the sidewalk will eventually stop the rider.

Newton's second law of motion states that the acceleration of an object depends on the mass of the object and the amount of force applied.

The first part of the law explains why the acceleration of a 4 kg bowling ball will be greater than the acceleration of a 6 kg bowling ball if the same force is applied to both.

The second part of the law explains why the acceleration of a bowling ball will be larger if a larger force is applied to the bowling ball.

The relationship of acceleration (a) to mass (m) and force (F) can be expressed mathematically by the following equation:

$$acceleration = \frac{force}{mass}, \text{ or } a = \frac{F}{m}$$

This equation is often rearranged to the form

$$force = mass \times acceleration$$

or

$$F = m \times a$$

Newton's third law of motion states that whenever one object exerts a force on a second object, the second object exerts an equal and opposite force on the first.

This law explains that a runner is able to move forward because of the equal and opposite force that the ground exerts on the runner's foot after each step.

Appendix

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Useful Equations

Average speed

$$\textit{average speed} = \frac{\textit{total distance}}{\textit{total time}}$$

Example: A bicycle messenger traveled a distance of 136 km in 8 h. What was the messenger's average speed?

$$\frac{136 \text{ km}}{8 \text{ h}} = 17 \text{ km/h}$$

The messenger's average speed was **17 km/h.**

Average acceleration

$$\textit{average acceleration} = \frac{\textit{final velocity} - \textit{starting velocity}}{\textit{time it takes to change velocity}}$$

Example: Calculate the average acceleration of an Olympic 100 m dash sprinter who reaches a velocity of 20 m/s south at the finish line. The race was in a straight line and lasted 10 s.

$$\frac{20 \text{ m/s} - 0 \text{ m/s}}{10 \text{ s}} = 2 \text{ m/s/s}$$

The sprinter's average acceleration is **2 m/s/s south.**

Net force

Forces in the Same Direction

When forces are in the same direction, add the forces together to determine the net force.

Example: Calculate the net force on a stalled car that is being pushed by two people. One person is pushing with a force of 13 N northwest, and the other person is pushing with a force of 8 N in the same direction.

$$13 \text{ N} + 8 \text{ N} = 21 \text{ N}$$

The net force is **21 N northwest.**

Forces in Opposite Directions

When forces are in opposite directions, subtract the smaller force from the larger force to determine the net force. The net force will be in the direction of the larger force.

Net force (continued)

Example: Calculate the net force on a rope that is being pulled on each end. One person is pulling on one end of the rope with a force of 12 N south. Another person is pulling on the opposite end of the rope with a force of 7 N north.

$$12 \text{ N} - 7 \text{ N} = 5 \text{ N}$$

The net force is **5 N south.**

Density

$$\textit{density} = \frac{\textit{mass}}{\textit{volume}}$$

Example: Calculate the density of a sponge that has a mass of 10 g and a volume of 40 cm^3.

$$\frac{10 \text{ g}}{40 \text{ cm}^3} = \frac{0.25 \text{g}}{\text{cm}^3}$$

The density of the sponge is **0.25 g/cm^3.**

Pressure

Pressure is the force exerted over a given area. The SI unit for pressure is the pascal, whose symbol is Pa.

$$\textit{pressure} = \frac{\textit{force}}{\textit{area}}$$

Example: Calculate the pressure of the air in a soccer ball if the air exerts a force of 10 N over an area of 0.5 m^2.

$$\textit{pressure} = \frac{10 \text{ N}}{0.5 \text{ m}^2} = \frac{20 \text{ N}}{\text{m}^2} = 20 \text{ Pa}$$

The pressure of the air inside the soccer ball is **20 Pa.**

Concentration

$$\textit{concentration} = \frac{\textit{mass of solute}}{\textit{volume of solvent}}$$

Example: Calculate the concentration of a solution in which 10 g of sugar is dissolved in 125 mL of water.

$$\frac{10 \text{ g of sugar}}{125 \text{ mL of water}} = \frac{0.08 \text{ g}}{\text{mL}}$$

The concentration of this solution is **0.08 g/mL.**

Appendix

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Properties of Common Minerals

	Mineral	Color	Luster	Streak	Hardness
Silicate Minerals	**Beryl**	deep green, pink, white, bluish green, or yellow	vitreous	white	7.5–8
	Chlorite	green	vitreous to pearly	pale green	2–2.5
	Garnet	green, red, brown, black	vitreous	white	6.5–7.5
	Hornblende	dark green, brown, or black	vitreous	none	5–6
	Muscovite	colorless, silvery white, or brown	vitreous or pearly	white	2–2.5
	Olivine	olive green, yellow	vitreous	white or none	6.5–7
	Orthoclase	colorless, white, pink, or other colors	vitreous	white or none	6
	Plagioclase	colorless, white, yellow, pink, green	vitreous	white	6
	Quartz	colorless or white; any color when not pure	vitreous or waxy	white or none	7
Nonsilicate Minerals	**Native Elements**				
	Copper	copper-red	metallic	copper-red	2.5–3
	Diamond	pale yellow or colorless	adamantine	none	10
	Graphite	black to gray	submetallic	black	1–2
	Carbonates				
	Aragonite	colorless, white, or pale yellow	vitreous	white	3.5–4
	Calcite	colorless or white to tan	vitreous	white	3
	Halides				
	Fluorite	light green, yellow, purple, bluish green, or other colors	vitreous	none	4
	Halite	white	vitreous	white	2.0–2.5
	Oxides				
	Hematite	reddish brown to black	metallic to earthy	dark red to red-brown	5.6–6.5
	Magnetite	iron-black	metallic	black	5.5–6.5
	Sulfates				
	Anhydrite	colorless, bluish, or violet	vitreous to pearly	white	3–3.5
	Gypsum	white, pink, gray, or colorless	vitreous, pearly, or silky	white	2.0
	Sulfides				
	Galena	lead-gray	metallic	lead-gray to black	2.5–2.8
	Pyrite	brassy yellow	metallic	greenish, brownish, or black	6–6.5

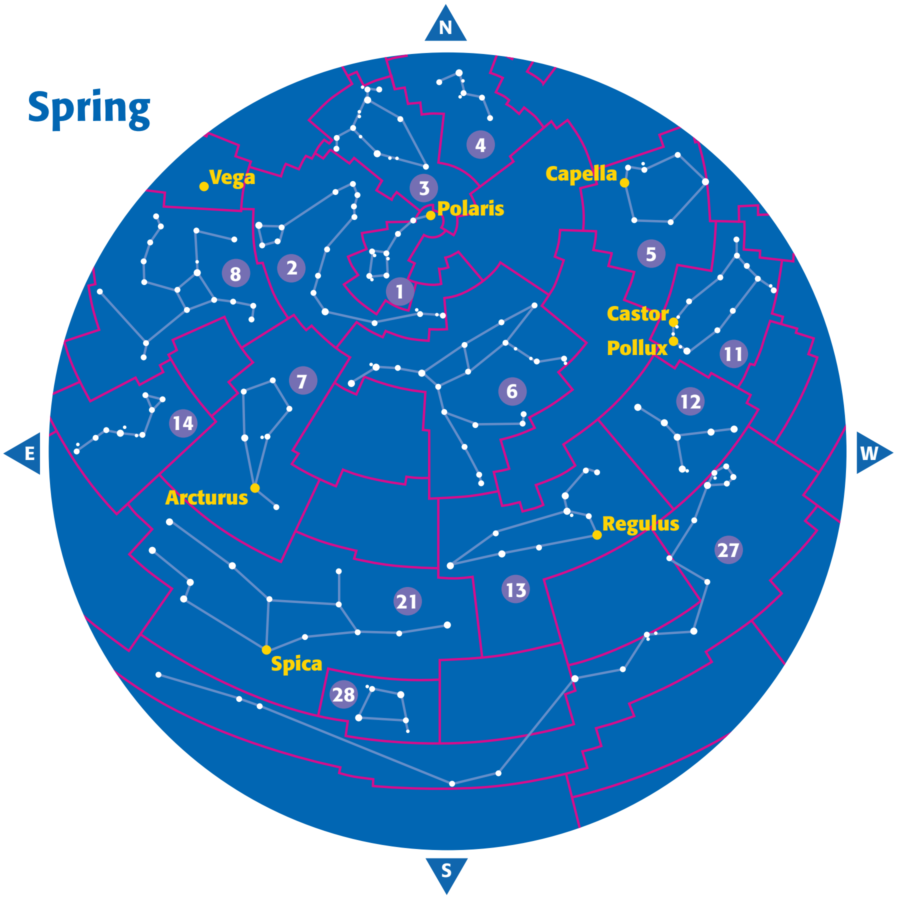
Copyright © by Holt, Rinehart and Winston. All rights reserved.

Density (g/cm^3)	Cleavage, Fracture, Special Properties	Common Uses
2.6–2.8	1 cleavage direction; irregular fracture; some varieties fluoresce in ultraviolet light	gemstones, ore of the metal beryllium
2.6–3.3	1 cleavage direction; irregular fracture	
4.2	no cleavage; conchoidal to splintery fracture	gemstones, abrasives
3.0–3.4	2 cleavage directions; hackly to splintery fracture	
2.7–3	1 cleavage direction; irregular fracture	electrical insulation, wallpaper, fireproofing material, lubricant
3.2–3.3	no cleavage; conchoidal fracture	gemstones, casting
2.6	2 cleavage directions; irregular fracture	porcelain
2.6–2.7	2 cleavage directions; irregular fracture	ceramics
2.6	no cleavage; conchoidal fracture	gemstones, concrete, glass, porcelain, sandpaper, lenses
8.9	no cleavage; hackly fracture	wiring, brass, bronze, coins
3.5	4 cleavage directions; irregular to conchoidal fracture	gemstones, drilling
2.3	1 cleavage direction; irregular fracture	pencils, paints, lubricants, batteries
2.95	2 cleavage directions; irregular fracture; reacts with hydrochloric acid	no important industrial uses
2.7	3 cleavage directions; irregular fracture; reacts with weak acid; double refraction	cements, soil conditioner, whitewash, construction materials
3.0–3.3	4 cleavage directions; irregular fracture; some varieties fluoresce	hydrofluoric acid, steel, glass, fiberglass, pottery, enamel
2.1–2.2	3 cleavage directions; splintery to conchoidal fracture; salty taste	tanning hides, salting icy roads, food preservation
5.2–5.3	no cleavage; splintery fracture; magnetic when heated	iron ore for steel, pigments
5.2	no cleavage; splintery fracture; magnetic	iron ore
3.0	3 cleavage directions; conchoidal to splintery fracture	soil conditioner, sulfuric acid
2.3	3 cleavage directions; conchoidal to splintery fracture	plaster of Paris, wallboard, soil conditioner
7.4–7.6	3 cleavage directions; irregular fracture	batteries, paints
5	no cleavage; conchoidal to splintery fracture	sulfuric acid

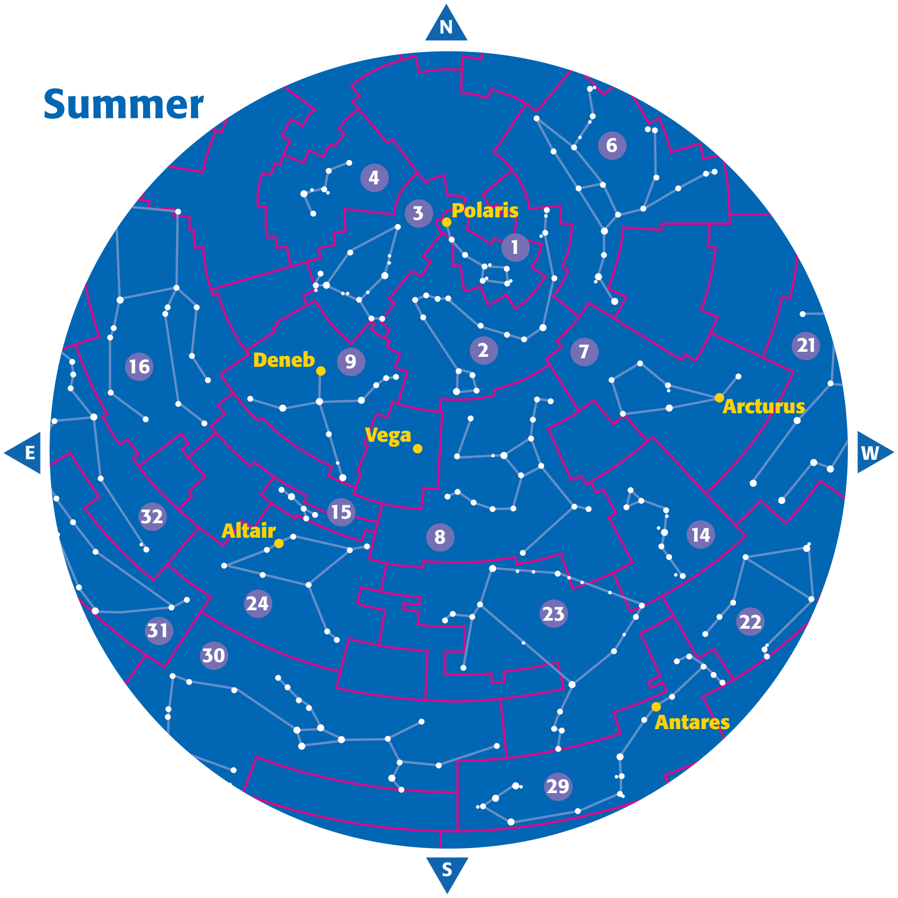
Copyright © by Holt, Rinehart and Winston. All rights reserved.

Sky Maps

Spring



Summer

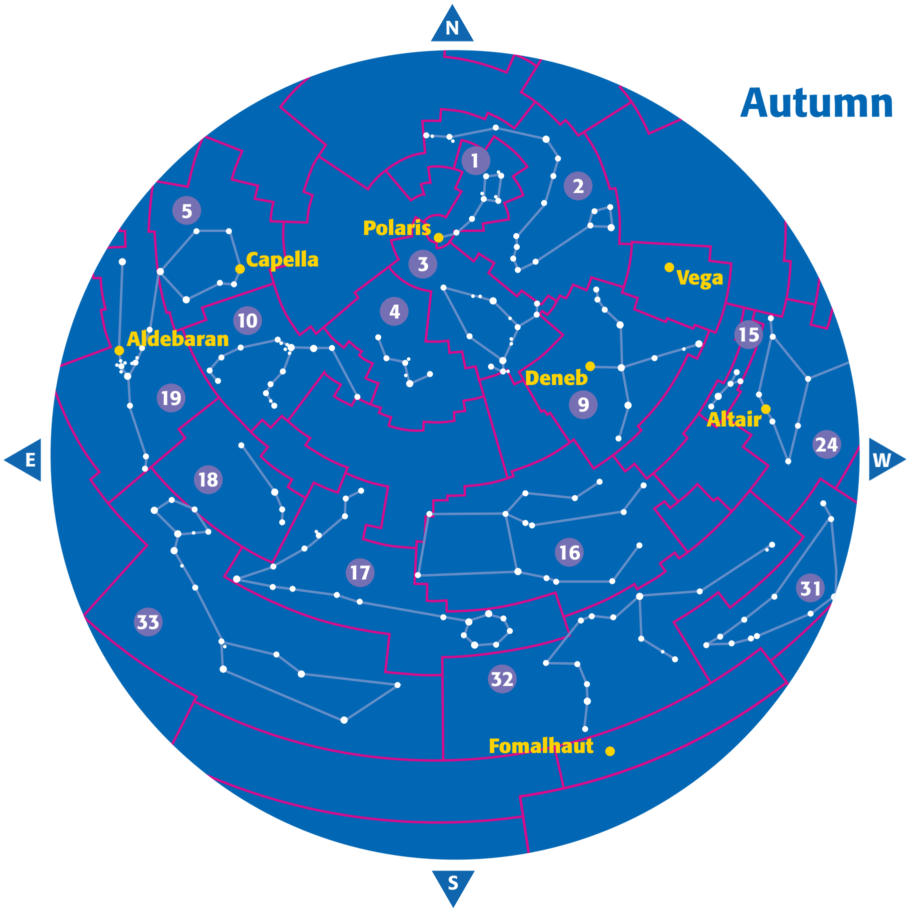


Constellations

1 Ursa Minor
2 Draco
3 Cepheus
4 Cassiopeia
5 Auriga
6 Ursa Major
7 Bootes
8 Hercules
9 Cygnus
10 Perseus
11 Gemini
12 Cancer
13 Leo
14 Serpens
15 Sagitta
16 Pegasus
17 Pisces

Copyright © by Holt, Rinehart and Winston. All rights reserved.

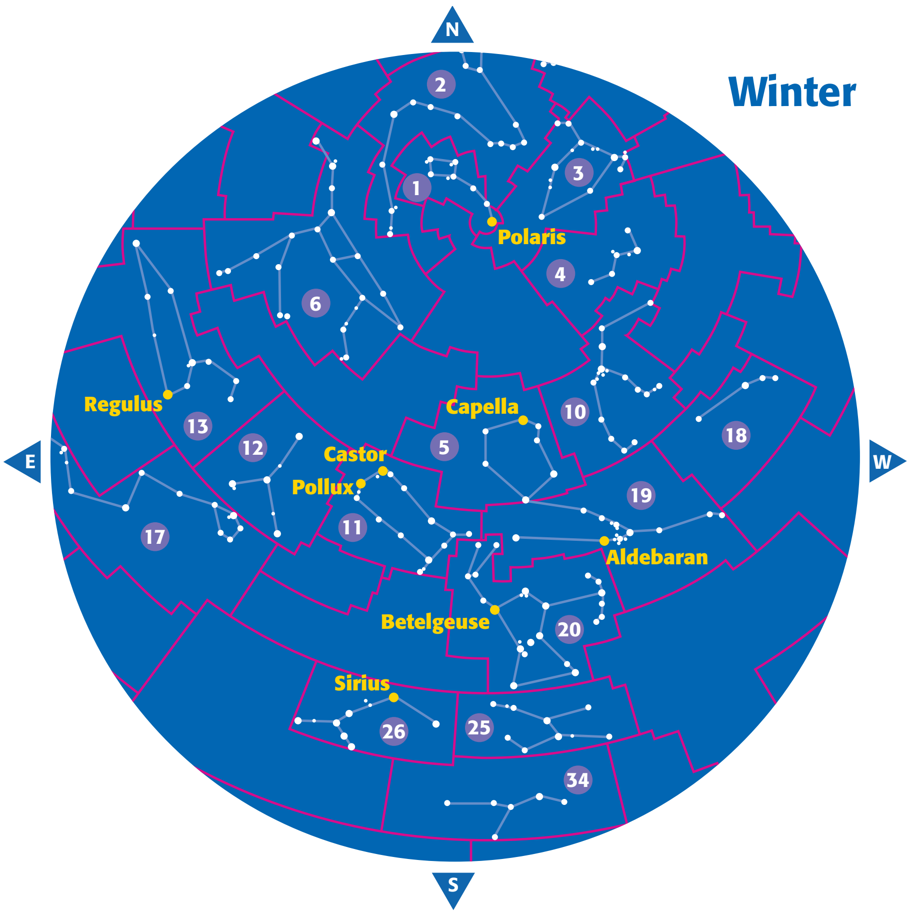
Autumn



Constellations

18 Aries
19 Taurus
20 Orion
21 Virgo
22 Libra
23 Ophiuchus
24 Aquila
25 Lepus
26 Canis Major
27 Hydra
28 Corvus
29 Scorpius
30 Sagittarius
31 Capricornus
32 Aquarius
33 Cetus
34 Columba

Winter



Copyright © by Holt, Rinehart and Winston. All rights reserved.

Glossary

A

abiotic describes the nonliving part of the environment, including water, rocks, light, and temperature (534)

abrasion the grinding and wearing away of rock surfaces through the mechanical action of other rock or sand particles (185, 225)

absolute zero the temperature at which molecular energy is at a minimum (0 K on the Kelvin scale or −273.16°C on the Celsius scale) (417)

absorption in optics, the transfer of light energy to particles of matter (506)

acid precipitation rain, sleet, or snow that contains a high concentration of acids (187)

adaptation a characteristic that improves an individual's ability to survive and reproduce in a particular environment (614)

amplitude the maximum distance that the particles of a wave's medium vibrate from their rest position (448)

area a measure of the size of a surface or a region (25)

artificial satellite any human-made object placed in orbit around a body in space (348)

asteroid a small, rocky object that orbits the sun, usually in a band between the orbits of Mars and Jupiter (330)

asteroid belt the region of the solar system that is between the orbits of Mars and Jupiter and in which most asteroids orbit (330)

asthenosphere the soft layer of the mantle on which the tectonic plates move (98)

astronomical unit the average distance between the Earth and the sun; approximately 150 million kilometers (symbol, AU) (309)

B

beach an area of the shoreline made up of material deposited by waves (222)

bedrock the layer of rock beneath soil (194)

biodiversity the number and variety of organisms in a given area during a specific period of time (594)

biosphere the part of Earth where life exists (537)

biotic describes living factors in the environment (534)

C

caldera a large, semicircular depression that forms when the magma chamber below a volcano partially empties and causes the ground above to sink (164)

carnivore an organism that eats animals (539)

carrying capacity the largest population that an environment can support at any given time (545)

cellular respiration the process by which cells use oxygen to produce energy from food (571)

chemical weathering the process by which rocks break down as a result of chemical reactions (187)

chlorophyll (KLAWR uh FIL) a green pigment that captures light energy for photosynthesis (570)

cleavage the splitting of a mineral along smooth, flat surfaces (45)

coevolution the evolution of two species that is due to mutual influence, often in a way that makes the relationship more beneficial to both species (549)

combustion the burning of a substance (564)

comet a small body of ice, rock, and cosmic dust that follows an elliptical orbit around the sun and that gives off gas and dust in the form of a tail as it passes close to the sun (328)

commensalism a relationship between two organisms in which one organism benefits and the other is unaffected (548)

community all of the populations of species that live in the same habitat and interact with each other (536)

composition the chemical makeup of a rock; describes either the minerals or other materials in the rock (69)

compound a substance made up of atoms of two or more different elements joined by chemical bonds (41)

compression stress that occurs when forces act to squeeze an object (112)

condensation the change of state from a gas to a liquid (562)

conservation (KAHN suhr VAY shuhn) the preservation and wise use of natural resources (596)

Copyright © by Holt, Rinehart and Winston. All rights reserved.

continental drift the hypothesis that states that the continents once formed a single landmass, broke up, and drifted to their present locations (104)

convection the transfer of thermal energy by the circulation or movement of a liquid or gas (425)

convergent boundary the boundary formed by the collision of two lithospheric plates (109)

core the central part of the Earth below the mantle (97, 293)

crater a funnel-shaped pit near the top of the central vent of a volcano (164)

creep the slow downhill movement of weathered rock material (237)

crust the thin and solid outermost layer of the Earth above the mantle (96, 293)

crystal a solid whose atoms, ions, or molecules are arranged in a definite pattern (41)

D

data any pieces of information acquired through observation or experimentation (13)

day the time required for Earth to rotate once on its axis (255)

decibel the most common unit used to measure loudness (symbol, dB) (478)

decomposition the breakdown of substances into simpler molecular substances (564)

deflation a form of wind erosion in which fine, dry soil particles are blown away (225)

deformation the bending, tilting, and breaking of the Earth's crust; the change in the shape of rock in response to stress (131)

density the ratio of the mass of a substance to the volume of the substance (46)

deposition the process in which material is laid down (65)

differential weathering the process by which softer, less weather resistant rocks wear away and leave harder, more weather resistant rocks behind (190)

diffraction a change in the direction of a wave when the wave finds an obstacle or an edge, such as an opening (454, 509)

divergent boundary the boundary between two tectonic plates that are moving away from each other (109)

Doppler effect an observed change in the frequency of a wave when the source or observer is moving (476)

dune a mound of wind-deposited sand that keeps its shape even though it moves (226)

E

echo a reflected sound wave (480)

echolocation the process of using reflected sound waves to find objects; used by animals such as bats (481)

eclipse an event in which the shadow of one celestial body falls on another (260)

ecology the study of the interactions of living organisms with one another and with their environment (534)

ecosystem a community of organisms and their abiotic, or nonliving, environment (537)

elastic rebound the sudden return of elastically deformed rock to its undeformed shape (131)

electromagnetic wave a wave that consists of electric and magnetic fields that vibrate at right angles to each other (500)

element a substance that cannot be separated or broken down into simpler substances by chemical means (40)

energy the capacity to do work (380)

energy conversion a change from one form of energy to another (388)

energy pyramid a triangular diagram that shows an ecosystem's loss of energy, which results as energy passes through the ecosystem's food chain (541)

epicenter the point on Earth's surface directly above an earthquake's starting point, or focus (136)

equinox the moment when the sun's path passes the celestial equator (256)

erosion the process by which wind, water, ice, or gravity transports soil and sediment from one location to another (65, 204)

evaporation the change of a substance from a liquid to a gas (562)

evolution the process in which inherited characteristics within a population change over generations such that new species sometimes arise (615)

Copyright © by Holt, Rinehart and Winston. All rights reserved.

extrusive igneous rock rock that forms as a result of volcanic activity at or near the Earth's surface (75)

F

farsightedness a condition in which the lens of the eye focuses distant objects behind rather than on the retina (519)

fault a break in a body of rock along which one block slides relative to another (114)

focus the point along a fault at which the first motion of an earthquake occurs (136)

folding the bending of rock layers due to stress (113)

foliated describes the texture of metamorphic rock in which the mineral grains are arranged in planes or bands (83)

food chain the pathway of energy transfer through various stages as a result of the feeding patterns of a series of organisms (540)

food web a diagram that shows the feeding relationships between organisms in an ecosystem (540)

fossil the remains or physical evidence of an organism preserved by geological processes (616)

fossil fuel a nonrenewable energy resource formed from the remains of organisms that lived long ago (398)

fossil record a historical sequence of life indicated by fossils found in layers of the Earth's crust (616)

fracture the manner in which a mineral breaks along either curved or irregular surfaces (45)

frequency the number of waves produced in a given amount of time (450)

friction a force that opposes motion between two surfaces that are in contact (394)

G

galaxy a collection of stars, dust, and gas bound together by gravity (278)

gap hypothesis a hypothesis that is based on the idea that a major earthquake is more likely to occur along the part of an active fault where no earthquakes have occurred for a certain period of time (141)

gas giant a planet that has a deep, massive atmosphere, such as Jupiter, Saturn, Uranus, or Neptune (318)

generation time the period between the birth of one generation and the birth of the next generation (629)

geostationary orbit an orbit that is about 36,000 km above the Earth's surface and in which a satellite is above a fixed spot on the equator (349)

glacial drift the rock material carried and deposited by glaciers (232)

glacier a large mass of moving ice (228)

globular cluster a tight group of stars that looks like a ball and contains up to 1 million stars (280)

H

hardness a measure of the ability of a mineral to resist scratching (46)

heat the energy transferred between objects that are at different temperatures (422)

herbivore an organism that eats only plants (539)

hot spot a volcanically active area of Earth's surface far from a tectonic plate boundary (170)

humus dark, organic material formed in soil from the decayed remains of plants and animals (196)

hypothesis (hie PAHTH uh sis) an explanation that is based on prior scientific research or observations and that can be tested (12)

I

interference the combination of two or more waves that results in a single wave (455, 482, 510)

intrusive igneous rock rock formed from the cooling and solidification of magma beneath the Earth's surface (74)

K

kinetic energy (ki NET ik EN uhr jee) the energy of an object that is due to the object's motion (381)

L

landslide the sudden movement of rock and soil down a slope (235)

lava plateau a wide, flat landform that results from repeated nonexplosive eruptions of lava that spread over a large area (165)

law a summary of many experimental results and observations; a law tells how things work (21)

law of conservation of energy the law that states that energy cannot be created or destroyed but can be changed from one form to another (395)

Copyright © by Holt, Rinehart and Winston. All rights reserved.

leaching the removal of substances that can be dissolved from rock, ore, or layers of soil due to the passing of water (196)

light-year the distance that light travels in one year; about 9.46 trillion kilometers (276)

limiting factor an environmental factor that prevents an organism or population from reaching its full potential of distribution or activity (574)

lithosphere the solid, outer layer of the Earth that consists of the crust and the rigid upper part of the mantle (98)

loess (LOH ES) very fertile sediments of quartz, feldspar, hornblende, mica, and clay deposited by the wind (226)

longitudinal wave a wave in which the particles of the medium vibrate parallel to the direction of wave motion (446)

loudness the extent to which a sound can be heard (477)

low Earth orbit an orbit that is less than 1,500 km above the Earth's surface (349)

luster the way in which a mineral reflects light (44)

M

magma chamber the body of molten rock that feeds a volcano (158)

mantle the layer of rock between the Earth's crust and core (97, 293)

mass a measure of the amount of matter in an object (25)

mass movement a movement of a section of land down a slope (234)

mechanical energy the amount of work an object can do because of the object's kinetic and potential energies (383)

mechanical weathering the breakdown of rock into smaller pieces by physical means (184)

medium a physical environment in which phenomena occur (443, 470)

mesosphere the strong, lower part of the mantle between the asthenosphere and the outer core (99)

meteor a bright streak of light that results when a meteoroid burns up in the Earth's atmosphere (331)

meteorite a meteoroid that reaches the Earth's surface without burning up completely (331)

meteoroid a relatively small, rocky body that travels through space (331)

meter the basic unit of length in the SI (symbol, m) (25)

mineral a naturally formed, inorganic solid that has a definite chemical structure (40)

model a pattern, plan, representation, or description designed to show the structure or workings of an object, system, or concept (18)

mudflow the flow of a mass of mud or rock and soil mixed with a large amount of water (236)

mutualism (MYOO choo uhl IZ uhm) a relationship between two species in which both species benefit (548)

N

NASA the **N**ational **A**eronautics and **S**pace **A**dministration (345)

natural selection the process by which individuals that are better adapted to their environment survive and reproduce more successfully than less well adapted individuals do; a theory to explain the mechanism of evolution (626)

neap tide a tide of minimum range that occurs during the first and third quarters of the moon (264)

nearsightedness a condition in which the lens of the eye focuses distant objects in front of rather than on the retina (519)

nebula a large cloud of gas and dust in interstellar space; a region in space where stars are born or where stars explode at the end of their lives (280)

noise a sound that consists of a random mix of frequencies (489)

nonfoliated describes the texture of metamorphic rock in which the mineral grains are not arranged in planes or bands (84)

nonrenewable resource a resource that forms at a rate that is much slower than the rate at which it is consumed (398, 592)

nonsilicate mineral a mineral that does not contain compounds of silicon and oxygen (42)

nuclear fusion the combination of the nuclei of small atoms to form a larger nucleus; releases energy (288)

Copyright © by Holt, Rinehart and Winston. All rights reserved.

O

observation the process of obtaining information by using the senses (11)

omnivore an organism that eats both plants and animals (539)

opaque (oh PAYK) describes an object that is not transparent or translucent (513)

open cluster a group of stars that are close together relative to surrounding stars (280)

orbit the path that a body follows as it travels around another body in space (250)

ore a natural material whose concentration of economically valuable minerals is high enough for the material to be mined profitably (50)

overpopulation the presence of too many individuals in an area for the available resources (593)

P

parasitism (PAR uh SIET IZ uhm) a relationship between two species in which one species, the parasite, benefits from the other species, the host, which is harmed (549)

parent rock a rock formation that is the source of soil (194)

phase the change in the sunlit area of one celestial body as seen from another celestial body (259)

photosynthesis (FOHT oh SIN thuh sis) the process by which plants, algae, and some bacteria use sunlight, carbon dioxide, and water to make food (570)

pigment a substance that gives another substance or a mixture its color (516)

pioneer species a species that colonizes an uninhabited area and that starts a process of succession (567)

pitch a measure of how high or low a sound is perceived to be, depending on the frequency of the sound wave (475)

plate tectonics the theory that explains how large pieces of the Earth's outermost layer, called *tectonic plates,* move and change shape (108)

pollution an unwanted change in the environment caused by substances or forms of energy (590)

population a group of organisms of the same species that live in a specific geographical area (536)

potential energy the energy that an object has because of the position, shape, or condition of the object (382)

precipitation any form of water that falls to the Earth's surface from the clouds (562)

predator an organism that eats all or part of another organism (546)

prey an organism that is killed and eaten by another organism (546)

prograde rotation the counterclockwise spin of a planet or moon as seen from above the planet's North Pole; rotation in the same direction as the sun's rotation (313)

P wave a seismic wave that causes particles of rock to move in a back-and-forth direction (134)

Q

quasar a very luminous, starlike object that generates energy at a high rate; quasars are thought to be the most distant objects in the universe (281)

R

radiation the transfer of energy as electromagnetic waves (426, 501)

reclamation the process of returning land to its original condition after mining is completed (51)

recycling the process of recovering valuable or useful materials from waste or scrap; the process of reusing some items (599)

reflection the bouncing back of a ray of light, sound, or heat when the ray hits a surface that it does not go through (452, 504)

refraction the bending of a wave as the wave passes between two substances in which the speed of the wave differs (453, 507)

renewable resource a natural resource that can be replaced at the same rate at which the resource is consumed (401, 592)

resonance a phenomenon that occurs when two objects naturally vibrate at the same frequency; the sound produced by one object causes the other object to vibrate (457, 484)

retrograde rotation the clockwise spin of a planet or moon as seen from above the planet's North Pole (313)

revolution the motion of a body that travels around another body in space; one complete trip along an orbit (250)

rift zone an area of deep cracks that forms between two tectonic plates that are pulling away from each other (168)

rock a naturally occurring solid mixture of one or more minerals or organic matter (64)

Copyright © by Holt, Rinehart and Winston. All rights reserved.

rock cycle the series of processes in which a rock forms, changes from one type to another, is destroyed, and forms again by geological processes (64)

rocket a machine that uses escaping gas from burning fuel to move (344)

rock fall the rapid mass movement of rock down a steep slope or cliff (235)

rotation the spin of a body on its axis (250)

S

salinization the accumulation of salts in soil (205)

saltation the movement of sand or other sediments by short jumps and bounces that is caused by wind or water (224)

satellite a natural or artificial body that revolves around a planet (324)

scattering an interaction of light with matter that causes light to change its energy, direction of motion, or both (506)

science the knowledge obtained by observing natural events and conditions in order to discover facts and formulate laws or principles that can be verified or tested (4)

scientific methods a series of steps followed to solve problems (10)

sea-floor spreading the process by which new oceanic lithosphere forms as magma rises toward the surface and solidifies (106)

seismic gap an area along a fault where relatively few earthquakes have occurred recently but where strong earthquakes have occurred in the past (141)

seismic wave a wave of energy that travels through the Earth and away from an earthquake in all directions (134)

seismogram a tracing of earthquake motion that is created by a seismograph (136)

seismograph an instrument that records vibrations in the ground and determines the location and strength of an earthquake (136)

seismology (siez MAHL uh jee) the study of earthquakes (130)

selective breeding the human practice of breeding animals or plants that have certain desired characteristics (624)

shoreline the boundary between land and a body of water (218)

silicate mineral a mineral that contains a combination of silicon, oxygen, and one or more metals (42)

soil a loose mixture of rock fragments, organic material, water, and air that can support the growth of vegetation (194)

soil conservation a method to maintain the fertility of the soil by protecting the soil from erosion and nutrient loss (202)

soil structure the arrangement of soil particles (195)

soil texture the soil quality that is based on the proportions of soil particles (195)

solar nebula the cloud of gas and dust that formed our solar system (283)

solstice the point at which the sun is as far north or as far south of the equator as possible (257)

sonic boom the explosive sound heard when a shock wave from an object traveling faster than the speed of sound reaches a person's ears (483)

sound quality the result of the blending of several pitches through interference (486)

sound wave a longitudinal wave that is caused by vibrations and that travels through a material medium (469)

space probe an uncrewed vehicle that carries scientific instruments into space to collect scientific data (354)

space shuttle a reusable space vehicle that takes off like a rocket and lands like an airplane (361)

space station a long-term orbiting platform from which other vehicles can be launched or scientific research can be carried out (362)

speciation (SPEE shee AY shuhn) the formation of new species as a result of evolution (630)

species a group of organisms that are closely related and can mate to produce fertile offspring (614)

specific heat the quantity of heat required to raise a unit mass of homogeneous material 1 K or 1°C in a specified way given constant pressure and volume (427)

spring tide a tide of increased range that occurs two times a month, at the new and full moons (264)

standing wave a pattern of vibration that simulates a wave that is standing still (456, 484)

stoma one of many openings in a leaf or a stem of a plant that enable gas exchange to occur (plural, *stomata*) (572)

strata layers of rock (singular, *stratum*) (76)

stratification the process in which sedimentary rocks are arranged in layers (79)

Copyright © by Holt, Rinehart and Winston. All rights reserved.

stratified drift a glacial deposit that has been sorted and layered by the action of streams or meltwater (233)

streak the color of the powder of a mineral (45)

subsidence (suhb SIED'ns) the sinking of regions of the Earth's crust to lower elevations (118)

succession the replacement of one type of community by another at a single location over a period of time (566)

sunspot a dark area of the photosphere of the sun that is cooler than the surrounding areas and that has a strong magnetic field (290)

S wave a seismic wave that causes particles of rock to move in a side-to-side direction (134)

symbiosis a relationship in which two different organisms live in close association with each other (548)

T

tectonic plate a block of lithosphere that consists of the crust and the rigid, outermost part of the mantle (100)

temperature a measure of how hot (or cold) something is; specifically, a measure of the average kinetic energy of the particles in an object (26, 414)

tension stress that occurs when forces act to stretch an object (112)

terrestrial planet one of the highly dense planets nearest to the sun; Mercury, Venus, Mars, and Earth (312)

texture the quality of a rock that is based on the sizes, shapes, and positions of the rock's grains (70)

theory an explanation that ties together many hypotheses and observations (20)

thermal conduction the transfer of energy as heat through a material (424)

thermal conductor a material through which energy can be transferred as heat (425)

thermal energy the kinetic energy of a substance's atoms (423)

thermal equilibrium the point at which two objects that are touching reach the same temperature (423)

thermal expansion an increase in the size of a substance in response to an increase in the temperature of the substance (416)

thermal insulator a material that reduces or prevents the transfer of heat (425)

thrust the pushing or pulling force exerted by the engine of an aircraft or rocket (346)

tidal range the difference in levels of ocean water at high tide and low tide (264)

tide the periodic rise and fall of the water level in the oceans and other large bodies of water (262)

till unsorted rock material that is deposited directly by a melting glacier (232)

trait a genetically determined characteristic (624)

transform boundary the boundary between tectonic plates that are sliding past each other horizontally (109)

translucent (trans LOO suhnt) describes matter that transmits light but that does not transmit an image (513)

transmission the passing of light or other form of energy through matter (512)

transparent describes matter that allows light to pass through with little interference (513)

transpiration the process by which plants release water vapor into the air through stomata; *also* the release of water vapor into the air by other organisms (572)

transverse wave a wave in which the particles of the medium move perpendicularly to the direction the wave is traveling (445)

U

uplift the rising of regions of the Earth's crust to higher elevations (118)

V

vent an opening at the surface of the Earth through which volcanic material passes (158)

volcano a vent or fissure in the Earth's surface through which magma and gases are expelled (156)

volume a measure of the size of a body or region in three-dimensional space (26)

W

wave a periodic disturbance in a solid, liquid, or gas as energy is transmitted through a medium (442)

wavelength the distance from any point on a wave to an identical point on the next wave (449)

wave speed the speed at which a wave travels through a medium (450)

weathering the process by which rock materials are broken down by the action of physical or chemical processes (184)

Glossary

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Spanish Glossary

A

abiotic/abiótico término que describe la parte sin vida del ambiente, incluyendo el agua, las rocas, la luz y la temperatura (534)

abrasion/abrasión proceso por el cual las superficies de las rocas se muelen o desgastan por medio de la acción mecánica de otras rocas y partículas de arena (185, 225)

absolute zero/cero absoluto la temperatura a la que la energía molecular es mínima (0 K en la escala de Kelvin ó –273.16°C en la escala de Celsius) (417)

absorption/absorción en la óptica, la transferencia de energía luminosa a las partículas de materia (506)

acid precipitation/precipitación ácida lluvia, aguanieve o nieve que contiene una alta concentración de ácidos (187)

adaptation/adaptación una característica que mejora la capacidad de un individuo para sobrevivir y reproducirse en un determinado ambiente (614)

amplitude/amplitud la distancia máxima a la que vibran las partículas del medio de una onda a partir de su posición de reposo (448)

area/área una medida del tamaño de una superficie o región (25)

artificial satellite/satélite artificial cualquier objeto hecho por los seres humanos y colocado en órbita alrededor de un cuerpo en el espacio (348)

asteroid/asteroide un objeto pequeño y rocoso que se encuentra en órbita alrededor del Sol, normalmente en una banda entre las órbitas de Marte y Júpiter (330)

asteroid belt/cinturón de asteroides la región del Sistema Solar que está entre las órbitas de Marte y Júpiter, en la que la mayoría de los asteroides se encuentran en órbita (330)

asthenosphere/astenosfera la capa blanda del manto sobre la que se mueven las placas tectónicas (98)

astronomical unit/unidad astronómica la distancia promedio entre la Tierra y el Sol; aproximadamente 150 millones de kilómetros (símbolo: UA) (309)

B

beach/playa un área de la costa formada por materiales depositados por las olas (222)

bedrock/lecho de roca la capa de rocas que está debajo del suelo (194)

biodiversity/biodiversidad el número y la variedad de organismos que se encuentran en un área determinada durante un período específico de tiempo (594)

biosphere/biosfera la parte de la Tierra donde existe la vida (537)

biotic/biótico término que describe los factores vivientes del ambiente (534)

C

caldera/caldera una depresión grande y semicircular que se forma cuando se vacía parcialmente la cámara de magma que hay debajo de un volcán, lo cual hace que el suelo se hunda (164)

carnivore/carnívoro un organismo que se alimenta de animales (539)

carrying capacity/capacidad de carga la población más grande que un ambiente puede sostener en cualquier momento dado (545)

cellular respiration/respiración celular el proceso por medio del cual las células utilizan oxígeno para producir energía a partir de los alimentos (571)

chemical weathering/desgaste químico el proceso por medio del cual las rocas se fragmentan como resultado de reacciones químicas (187)

chlorophyll/clorofila un pigmento verde que capta la energía luminosa para la fotosíntesis (570)

cleavage/exfoliación el agrietamiento de un mineral en sus superficies lisas y planas (45)

coevolution/coevolución la evolución de dos especies que se debe a su influencia mutua, a menudo de un modo que hace que la relación sea más beneficiosa para ambas (549)

combustion/combustión fenómeno que ocurre cuando una substancia se quema (564)

comet/cometa un cuerpo pequeño formado por hielo, roca y polvo cósmico que sigue una órbita elíptica alrededor del Sol y que libera gas y polvo, los cuales forman una cola al pasar cerca del Sol (328)

Copyright © by Holt, Rinehart and Winston. All rights reserved.

commensalism/comensalismo una relación entre dos organismos en la que uno se beneficia y el otro no es afectado (548)

community/comunidad todas las poblaciones de especies que viven en el mismo hábitat e interactúan entre sí (536)

composition/composición la constitución química de una roca; describe los minerales u otros materiales presentes en ella (69)

compound/compuesto una substancia formada por átomos de dos o más elementos diferentes unidos por enlaces químicos (41)

compression/compresión estrés que se produce cuando distintas fuerzas actúan para estrechar un objeto (112)

condensation/condensación el cambio de estado de gas a líquido (562)

conservation/conservación la preservación y el uso inteligente de los recursos naturales (596)

continental drift/deriva continental la hipótesis que establece que alguna vez los continentes formaron una sola masa de tierra, se dividieron y se fueron a la deriva hasta terminar en sus ubicaciones actuales (104)

convection/convección la transferencia de energía térmica mediante la circulación o el movimiento de un líquido o gas (425)

convergent boundary/límite convergente el límite que se forma debido al choque de dos placas de la litosfera (109)

core/núcleo la parte central de la Tierra, debajo del manto (97, 293)

crater/cráter una depresión con forma de embudo que se encuentra cerca de la parte superior de la chimenea central de un volcán (164)

creep/arrastre el movimiento lento y descendente de materiales rocosos desgastados (237)

crust/corteza la capa externa, delgada y sólida de la Tierra, que se encuentra sobre el manto (96, 293)

crystal/cristal un sólido cuyos átomos, iones o moléculas están ordenados en un patrón definido (41)

D

data/datos cualquier parte de la información que se adquiere por medio de la observación o experimentación (13)

day/día el tiempo que se requiere para que la Tierra rote una vez sobre su eje (255)

decibel/decibel la unidad más común que se usa para medir el volumen del sonido (símbolo: dB) (478)

decomposition/descomposición la desintegración de substancias en substancias moleculares más simples (564)

deflation/deflación una forma de erosión del viento en la que se mueven partículas de suelo finas y secas (225)

deformation/deformación el proceso de doblar, inclinar y romper la corteza de la Tierra; el cambio en la forma de una roca en respuesta a la tensión (131)

density/densidad la relación entre la masa de una substancia y su volumen (46)

deposition/deposición el proceso por medio del cual un material se deposita (65)

differential weathering/desgaste diferencial el proceso por medio cual las rocas más suaves y menos resistentes al clima se desgastan y las rocas más duras y resistentes al clima permanecen (190)

diffraction/difracción un cambio en la dirección de una onda cuando ésta se encuentra con un obstáculo o un borde, tal como una abertura (454, 509)

divergent boundary/límite divergente el límite entre dos placas tectónicas que se están separando una de la otra (109)

Doppler effect/efecto Doppler un cambio que se observa en la frecuencia de una onda cuando la fuente o el observador está en movimiento (476)

dune/duna un montículo de arena depositada por el viendo que conserva su forma incluso cuando se mueve (226)

E

echo/eco una onda de sonido reflejada (480)

echolocation/ecolocación el proceso de usar ondas de sonido reflejadas para buscar objetos; utilizado por animales tales como los murciélagos (481)

eclipse/eclipse un suceso en el que la sombra de un cuerpo celeste cubre otro cuerpo celeste (260)

ecology/ecología el estudio de las interacciones de los seres vivos entre sí mismos y entre sí mismos y su ambiente (534)

ecosystem/ecosistema una comunidad de organismos y su ambiente abiótico o no vivo (537)

elastic rebound/rebote elástico ocurre cuando una roca deformada elásticamente vuelve súbitamente a su forma no deformada (131)

Copyright © by Holt, Rinehart and Winston. All rights reserved.

electromagnetic wave/onda electromagnética una onda que está formada por campos eléctricos y magnéticos que vibran formando un ángulo recto unos con otros (500)

element/elemento una substancia que no se puede separar o descomponer en substancias más simples por medio de métodos químicos (40)

energy/energía la capacidad de realizar un trabajo (380)

energy conversion/transformación de energía un cambio de un tipo de energía a otro (388)

energy pyramid/pirámide de energía un diagrama triangular que muestra la pérdida de energía en un ecosistema, producida a medida que la energía pasa a través de la cadena alimenticia del ecosistema (541)

epicenter/epicentro el punto de la superficie de la Tierra que queda justo arriba del punto de inicio, o foco, de un terremoto (136)

equinox/equinoccio el momento en que el camino del Sol cruza el ecuador celeste (256)

erosion/erosión el proceso por medio del cual el viento, el agua, el hielo o la gravedad transporta tierra y sedimentos de un lugar a otro (65, 204)

evaporation/evaporación el cambio de una substancia de líquido a gas (562)

evolution/evolución el proceso por medio del cual las características heredadas dentro de una población cambian con el transcurso de las generaciones de manera tal que a veces surgen nuevas especies (615)

extrusive igneous rock/roca ígnea extrusiva una roca que se forma como resultado de la actividad volcánica en la superficie de la Tierra o cerca de ella (75)

F

farsightedness/hipermetropía condición en la que el cristalino del ojo enfoca los objetos lejanos detrás de la retina en lugar de en ella (519)

fault/falla una grieta en un cuerpo rocoso a lo largo de la cual un bloque se desliza respecto a otro (114)

focus/foco el punto a lo largo de una falla donde ocurre el primer movimiento de un terremoto (136)

folding/plegamiento fenómeno que ocurre cuando las capas de roca se doblan debido a la compresión (113)

foliated/foliada término que describe la textura de una roca metamórfica en la que los granos de mineral están ordenados en planos o bandas (83)

food chain/cadena alimenticia la vía de transferencia de energía través de varias etapas, que ocurre como resultado de los patrones de alimentación de una serie de organismos (540)

food web/red alimenticia un diagrama que muestra las relaciones de alimentación entre los organismos de un ecosistema (540)

fossil/fósil los restos o las pruebas físicas de un organismo preservados por los procesos geológicos (616)

fossil fuel/combustible fósil un recurso energético no renovable formado a partir de los restos de organismos que vivieron hace mucho tiempo (398)

fossil record/registro fósil una secuencia histórica de la vida indicada por fósiles que se han encontrado en las capas de la corteza terrestre (616)

fracture/fractura la forma en la que se rompe un mineral a lo largo de superficies curvas o irregulares (45)

frequency/frecuencia el número de ondas producidas en una cantidad de tiempo determinada (450)

friction/fricción una fuerza que se opone al movimiento entre dos superficies que están en contacto (394)

G

galaxy/galaxia un conjunto de estrellas, polvo y gas unidos por la gravedad (278)

gap hypothesis/hipótesis del intervalo una hipótesis que se basa en la idea de que es más probable que ocurra un terremoto importante a lo largo de la parte de una falla activa donde no se han producido terremotos durante un determinado período de tiempo (141)

gas giant/gigante gaseoso un planeta con una atmósfera masiva y profunda, como por ejemplo, Júpiter, Saturno, Urano o Neptuno (318)

generation time/tiempo de generación el período entre el nacimiento de una generación y el nacimiento de la siguiente generación (629)

geostationary orbit/órbita geoestacionaria una órbita que está a aproximadamente 36,000 km de la superficie terrestre, en la que un satélite permanece sobre un punto fijo en el ecuador (349)

glacial drift/deriva glacial el material rocoso que es transportado y depositado por los glaciares (232)

glacier/glaciar una masa grande de hielo en movimiento (228)

globular cluster/cúmulo globular un grupo compacto de estrellas que parece una bola y contiene hasta un millón de estrellas (280)

Copyright © by Holt, Rinehart and Winston. All rights reserved.

H

hardness/dureza una medida de la capacidad de un mineral de resistir ser rayado (46)

heat/calor la transferencia de energía entre objetos que están a temperaturas diferentes (422)

herbivore/herbívoro un organismo que sólo come plantas (539)

hot spot/mancha caliente un área volcánicamente activa de la superficie de la Tierra que se encuentra lejos de un límite entre placas tectónicas (170)

humus/humus material orgánico obscuro que se forma en la tierra a partir de restos de plantas y animales en descomposición (196)

hypothesis/hipótesis una explicación que se basa en observaciones o investigaciones científicas previas y que se puede probar (12)

I

interference/interferencia la combinación de dos o más ondas que resulta en una sola onda (455, 482, 510)

intrusive igneous rock/roca ígnea intrusiva una roca formada a partir del enfriamiento y solidificación del magma debajo de la superficie terrestre (74)

K

kinetic energy/energía cinética la energía de un objeto debido al movimiento del objeto (381)

L

landslide/derrumbamiento el movimiento súbito hacia abajo de rocas y suelo por una pendiente (235)

lava plateau/meseta de lava un accidente geográfico amplio y plano que se forma debido a repetidas erupciones no explosivas de lava que se expanden por un área extensa (165)

law/ley un resumen de muchos resultados y observaciones experimentales; una ley dice cómo funcionan las cosas (21)

law of conservation of energy/ley de la conservación de la energía la ley que establece que la energía ni se crea ni se destruye, sólo se transforma de una forma a otra (395)

leaching/lixiviación la remoción de substancias que pueden disolverse de rocas, menas o capas de suelo debido al paso del agua (196)

light-year/año luz la distancia que viaja la luz en un año; aproximadamente 9.46 trillones de kilómetros (276)

limiting factor/factor limitante un factor ambiental que impide que un organismo o población alcance su máximo potencial de distribución o de actividad (574)

lithosphere/litosfera la capa externa y sólida de la Tierra que está formada por la corteza y la parte superior y rígida del manto (98)

loess/loess sedimentos muy fértiles de cuarzo, feldespato, horneblenda, mica y arcilla depositados por el viento (226)

longitudinal wave/onda longitudinal una onda en la que las partículas del medio vibran paralelamente a la dirección del movimiento de la onda (446)

loudness/volumen el grado al que se escucha un sonido (477)

low Earth orbit/órbita terrestre baja una órbita ubicada a menos de 1,500 km sobre la superficie terrestre (349)

luster/brillo la forma en que un mineral refleja la luz (44)

M

magma chamber/cámara de magma la masa de roca fundida que alimenta un volcán (158)

mantle/manto la capa de roca que se encuentra entre la corteza terrestre y el núcleo (97, 293)

mass/masa una medida de la cantidad de materia que tiene un objeto (25)

mass movement/movimiento masivo un movimiento hacia abajo de una sección de terreno por una pendiente (234)

mechanical energy/energía mecánica la cantidad de trabajo que un objeto realiza debido a las energías cinética y potencial del objeto (383)

mechanical weathering/desgaste mecánico el rompimiento de una roca en pedazos más pequeños mediante medios físicos (184)

medium/medio un ambiente físico en el que ocurren fenómenos (443, 470)

mesosphere/mesosfera la parte fuerte e inferior del manto que se encuentra entre la astenosfera y el núcleo externo (99)

meteor/meteoro un rayo de luz brillante que se produce cuando un meteoroide se quema en la atmósfera de la Tierra (331)

meteorite/meteorito un meteoroide que llega a la superficie de la Tierra sin quemarse por completo (331)

meteoroid/meteoroide un cuerpo rocoso relativamente pequeño que viaja en el espacio (331)

Spanish Glossary

Copyright © by Holt, Rinehart and Winston. All rights reserved.

meter/metro la unidad fundamental de longitud en el sistema internacional de unidades (símbolo: m) (25)

mineral/mineral un sólido natural e inorgánico que tiene una estructura química definida (40)

model/modelo un diseño, plan, representación o descripción cuyo objetivo es mostrar la estructura o funcionamiento de un objeto, sistema o concepto (18)

mudflow/flujo de lodo el flujo de una masa de lodo o roca y suelo mezclados con una gran cantidad de agua (236)

mutualism/mutualismo una relación entre dos especies en la que ambas se benefician (548)

N

NASA/NASA la Administración Nacional de Aeronáutica y del Espacio (345)

natural selection/selección natural el proceso por medio del cual los individuos que están mejor adaptados a su ambiente sobreviven y se reproducen con más éxito que los individuos menos adaptados; una teoría que explica el mecanismo de la evolución (626)

neap tide/marea muerta una marea que tiene un rango mínimo, la cual ocurre durante el primer y el tercer cuartos de la Luna (264)

nearsightedness/miopía condición en la que el cristalino del ojo enfoca los objetos lejanos delante de la retina en lugar de en ella (519)

nebula/nebulosa una nube grande de gas y polvo en el espacio interestelar; una región en el espacio donde las estrellas nacen o donde explotan al final de su vida (280)

noise/ruido un sonido que está constituido por una mezcla aleatoria de frecuencias (489)

nonfoliated/no foliada término que describe la textura de una roca metamórfica en la que los granos de mineral no están ordenados en planos ni bandas (84)

nonrenewable resource/recurso no renovable un recurso que se forma a una tasa que es mucho más lenta que la tasa a la que se consume (398, 592)

nonsilicate mineral/mineral no-silicato un mineral que no contiene compuestos de sílice y oxígeno (42)

nuclear fusion/fusión nuclear combinación de los núcleos de átomos pequeños para formar un núcleo más grande; libera energía (288)

O

observation/observación el proceso de obtener información por medio de los sentidos (11)

omnivore/omnívoro un organismo que come tanto plantas como animales (539)

opaque/opaco término que describe un objeto que no es transparente ni translúcido (513)

open cluster/conglomerado abierto un grupo de estrellas que se encuentran juntas respecto a las estrellas que las rodean (280)

orbit/órbita la trayectoria que sigue un cuerpo al desplazarse alrededor de otro cuerpo en el espacio (250)

ore/mena un material natural cuya concentración de minerales con valor económico es suficientemente alta como para que el material pueda ser explotado de manera rentable (50)

overpopulation/sobrepoblación la presencia de demasiados individuos en un área para los recursos disponibles (593)

P

parasitism/parasitismo una relación entre dos especies en la que una, el parásito, se beneficia de la otra, el huésped, que resulta perjudicada (549)

parent rock/roca precursora una formación rocosa que es la fuente a partir de la cual se origina el suelo (194)

phase/fase el cambio en el área iluminada de un cuerpo celeste según se ve desde otro cuerpo celeste (259)

photosynthesis/fotosíntesis el proceso por medio del cual las plantas, las algas y algunas bacterias utilizan la luz solar, el dióxido de carbono y el agua para producir alimento (570)

pigment/pigmento una substancia que le da color a otra substancia o mezcla (516)

pioneer species/especie pionera una especie que coloniza un área deshabitada y empieza un proceso de sucesión (567)

pitch/altura tonal una medida de qué tan agudo o grave se percibe un sonido, dependiendo de la frecuencia de la onda sonora (475)

plate tectonics/tectónica de placas la teoría que explica cómo se mueven y cambian de forma las placas tectónicas, que son grandes porciones de la capa más externa de la Tierra (108)

Copyright © by Holt, Rinehart and Winston. All rights reserved.

pollution/contaminación un cambio indeseable en el ambiente producido por substancias dañinas, desechos, gases, ruidos o radiación (590)

population/población un grupo de organismos de la misma especie que viven en un área geográfica específica (536)

potential energy/energía potencial la energía que tiene un objeto debido a su posición, forma o condición (382)

precipitation/precipitación cualquier forma deagua que cae de las nubes a la superficie de la Tierra (562)

predator/depredador un organismo que se alimenta de otro organismo o de parte de él (546)

prey/presa un organismo al que otro organismo mata para alimentarse de él (546)

prograde rotation/rotación progresiva el giro en contra de las manecillas del reloj de un planeta o de una luna según lo vería un observador ubicado encima del Polo Norte del planeta; rotación en la misma dirección que la rotación del Sol (313)

P wave/onda P una onda sísmica que hace que las partículas de roca se muevan en una dirección de atrás hacia delante (134)

Q

quasar/cuasar un objeto muy luminoso, parecido a una estrella, que genera energía a una gran velocidad; se piensa que los cuásares son los objetos más distantes del universo (281)

R

radiation/radiación la transferencia de energía en forma de ondas electromagnéticas (426, 501)

reclamation/restauración el proceso de hacer que la tierra vuelva a su condición original después de que se terminan las actividades de explotación minera (51)

recycling/reciclar el proceso de recuperar materiales valiosos o útiles de los desechos o de la basura; el proceso de reutilizar algunas cosas (599)

reflection/reflexión el rebote de un rayo de luz, sonido o calor cuando el rayo golpea una superficie pero no la atraviesa (452, 504)

refraction/refracción el curvamiento de una onda cuando ésta pasa entre dos substancias en las que su velocidad difiere (453, 507)

renewable resource/recurso renovable un recurso natural que puede reemplazarse a la misma tasa a la que se consume (401, 592)

resonance/resonancia un fenómeno que ocurre cuando dos objetos vibran naturalmente a la misma frecuencia; el sonido producido por un objeto hace que el otro objeto vibre (457, 484)

retrograde rotation/rotación retrógrada el giro en el sentido de las manecillas del reloj de un planeta o de una luna según lo vería un observador ubicado encima del Polo Norte del planeta (313)

revolution/revolución el movimiento de un cuerpo que viaja alrededor de otro cuerpo en el espacio; un viaje completo a lo largo de una órbita (250)

rift zone/zona de rift un área de grietas profundas que se forma entre dos placas tectónicas que se están alejando una de la otra (168)

rock/roca una mezcla sólida de uno o más minerales o de materia orgánica que se produce de forma natural (64)

rock cycle/ciclo de las rocas la serie de procesos por medio de los cuales una roca se forma, cambia de un tipo a otro, se destruye y se forma nuevamente por procesos geológicos (64)

rocket/cohete un aparato que para moverse utiliza el gas de escape que se origina a partir de la combustión (344)

rock fall/desprendimiento de rocas el movimiento rápido y masivo de rocas por una pendiente empinada o un precipicio (235)

rotation/rotación el giro de un cuerpo alrededor de su eje (250)

S

salinization/salinización la acumulación de sales en el suelo (205)

saltation/saltación el movimiento de la arena u otros sedimentos por medio de saltos pequeños y rebotes debido al viento o al agua (224)

satellite/satélite un cuerpo natural o artificial que gira alrededor de un planeta (324)

scattering/dispersión una interacción de la luz con la materia que hace que la luz cambie su energía, la dirección del movimiento o ambas (506)

science/ciencia el conocimiento que se obtiene por medio de la observación natural de acontecimientos y condiciones con el fin de descubrir hechos y formular leyes o principios que puedan ser verificados o probados (4)

scientific methods/métodos científicos una serie de pasos que se siguen para solucionar problemas (10)

Copyright © by Holt, Rinehart and Winston. All rights reserved.

sea-floor spreading/expansión del suelo marino el proceso por medio del cual se forma nueva litosfera oceánica a medida que el magma se eleva hacia la superficie y se solidifica (106)

seismic gap/brecha sísmica un área a lo largo de una falla donde han ocurrido relativamente pocos terremotos recientemente, pero donde se han producido terremotos fuertes en el pasado (141)

seismic wave/onda sísmica una onda de energía que viaja a través de la Tierra y se aleja de un terremoto en todas direcciones (134)

seismogram/sismograma una gráfica del movimiento de un terremoto elaborada por un sismógrafo (136)

seismograph/sismógrafo un instrumento que registra las vibraciones en el suelo y determina la ubicación y la fuerza de un terremoto (136)

seismology/sismología el estudio de los terremotos (130)

selective breeding/reproducción selectiva la práctica humana de cruzar animales o plantas que tienen ciertas características deseadas (624)

shoreline/orilla el límite entre la tierra y una masa de agua (218)

silicate mineral/mineral silicato un mineral que contiene una combinación de sílice, oxígeno y uno o más metales (42)

soil/suelo una mezcla suelta de fragmentos de roca, material orgánico, agua y aire en la que puede crecer vegetación (194)

soil conservation/conservación del suelo un método para mantener la fertilidad del suelo protegiéndolo de la erosión y la pérdida de nutrientes (202)

soil structure/estructura del suelo la organización de las partículas del suelo (195)

soil texture/textura del suelo la cualidad del suelo que se basa en las proporciones de sus partículas (195)

solar nebula/nebulosa solar la nube de gas y polvo que formó nuestro Sistema Solar (283)

solstice/solsticio el punto en el que el Sol está tan lejos del ecuador como es posible, ya sea hacia el norte o hacia el sur (257)

sonic boom/estampido sónico el sonido explosivo que se escucha cuando la onda de choque de un objeto que se desplaza a una velocidad superior a la de la luz llega a los oídos de una persona (483)

sound quality/calidad del sonido el resultado de la combinación de varios tonos por medio de la interferencia (486)

sound wave/onda de sonido una onda longitudinal que se origina debido a vibraciones y que se desplaza a través de un medio material (469)

space probe/sonda espacial un vehículo no tripulado que lleva instrumentos científicos al espacio con el fin de recopilar información científica (354)

space shuttle/transbordador espacial un vehículo espacial reutilizable que despega como un cohete y aterriza como un avión (361)

space station/estación espacial una plataforma orbital de largo plazo desde la cual pueden lanzarse otros vehículos o en la que pueden realizarse investigaciones científicas (362)

speciation/especiación la formación de especies nuevas como resultado de la evolución (630)

species/especie un grupo de organismos que tienen un parentesco cercano y que pueden aparearse para producir descendencia fértil (614)

specific heat/calor específico la cantidad de calor que se requiere para aumentar una unidad de masa de un material homogéneo 1 K ó 1°C de una manera especificada, dados un volumen y una presión constantes (427)

spring tide/marea muerta una marea de mayor rango que ocurre dos veces al mes, durante la luna nueva y la luna llena (264)

standing wave/onda estacionaria un patrón de vibración que simula una onda que está parada (456, 484)

stoma/estoma una de las muchas aberturas de una hoja o de un tallo de una planta, la cual permite que se lleve a cabo el intercambio de gases (572)

strata/estratos capas de roca (76)

stratification/estratificación el proceso por medio del cual las rocas sedimentarias se acomodan en capas (79)

stratified drift/deriva estratificada un depósito glacial que ha formado capas debido a la acción de los arroyos o de las aguas de ablación (233)

streak/veta el color del polvo de un mineral (45)

subsidence/hundimiento del terreno el hundimiento de regiones de la corteza terrestre a elevaciones más bajas (118)

succession/sucesión el reemplazo de un tipo de comunidad por otro en un mismo lugar a lo largo de un período de tiempo (566)

sunspot/mancha solar un área oscura en la fotosfera del Sol que es más fría que las áreas que la rodean y que tiene un campo magnético fuerte (290)

Copyright © by Holt, Rinehart and Winston. All rights reserved.

S wave/onda S una onda sísmica que hace que las partículas de roca se muevan en una dirección de lado a lado (134)

symbiosis/simbiosis una relación en la que dos organismos diferentes viven estrechamente asociados uno con el otro (548)

T

tectonic plate/placa tectónica un bloque de litosfera formado por la corteza y la parte rígida y más externa del manto (100)

temperature/temperatura una medida de qué tan caliente (o frío) está algo; específicamente, una medida de la energía cinética promedio de las partículas de un objeto (26, 414)

tension/tensión estrés que se produce cuando distintas fuerzas actúan para estirar un objeto (112)

terrestrial planet/planeta terrestre uno de los planetas muy densos que se encuentran más cerca del Sol; Mercurio, Venus, Marte y la Tierra (312)

texture/textura la cualidad de una roca que se basa en el tamaño, la forma y la posición de los granos que la forman (70)

theory/teoría una explicación que relaciona muchas hipótesis y observaciones (20)

thermal conduction/conducción térmica la transferencia de energía en forma de calor a través de un material (424)

thermal conductor/conductor térmico un material a través del cual es posible transferir energía en forma de calor (425)

thermal energy/energía térmica la energía cinética de los átomos de una sustancia (423)

thermal equilibrium/equilibrio térmica el punto en el que dos objetos que están en contracto llegan a la misma temperatura (423)

thermal expansion/expansión térmica un aumento en el tamaño de una sustancia en respuesta a un aumento en la temperatura de la sustancia (416)

thermal insulator/aislante térmico un material que reduce o evita la transferencia de calor (425)

thrust/empuje la fuerza de empuje o arrastre ejercida por el motor de un avión o cohete (346)

tidal range/rango de marea la diferencia en los niveles del agua del océano entre la marea alta y la marea baja (264)

tide/marea el ascenso y descenso periódico del nivel del agua en los océanos y otras masas grandes de agua (262)

till/arcilla glaciárica material rocoso desordenado que deposita directamente un glaciar que se está derritiendo (232)

trait/carácter una característica determinada genéticamente (624)

transform boundary/límite de transformación el límite entre placas tectónicas que se están deslizando horizontalmente una sobre otra (109)

translucent/traslúcido término que describe la materia que transmite luz, pero que no transmite una imagen (513)

transmission/transmisión el paso de la luz u otra forma de energía a través de la materia (512)

transparent/transparente término que describe materia que permite el paso de la luz con poca interferencia (513)

transpiration/transpiración el proceso por medio del cual las plantas liberan vapor de agua al aire por medio de los estomas; *también,* la liberación de vapor de agua al aire por otros organismos (572)

transverse wave/onda transversal una onda en la que las partículas del medio se mueven perpendicularmente respecto a la dirección en la que se desplaza la onda (445)

U

uplift/levantamiento la elevación de regiones de la corteza terrestre a elevaciones más altas (118)

V

vent/chimenea una abertura en la superficie de la Tierra a través de la cual pasa material volcánico (158)

volcano/volcán una chimenea o fisura en la superficie de la Tierra a través de la cual se expulsan magma y gases (156)

volume/volumen una medida del tamaño de un cuerpo o región en un espacio de tres dimensiones (26)

W

wave/onda una perturbación periódica en un sólido, líquido o gas que se transmite a través de un medio en forma de energía (442)

wavelength/longitud de onda la distancia entre cualquier punto de una onda y un punto idéntico en la onda siguiente (449)

wave speed/rapidez de onda la rapidez a la cual viaja una onda a través de un medio (450)

weathering/meteorización el proceso por el cual se desintegran los materiales que forman las rocas debido a la acción de procesos físicos o químicos (184)

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Index

Boldface page numbers refer to illustrative material, such as figures, tables, margin elements, photographs, and illustrations.

A

B

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Index

Copyright © by Holt, Rinehart and Winston. All rights reserved.

D

E

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Index

Copyright © by Holt, Rinehart and Winston. All rights reserved.

F

Copyright © by Holt, Rinehart and Winston. All rights reserved.

G

H

Copyright © by Holt, Rinehart and Winston. All rights reserved.

I

J

K

Copyright © by Holt, Rinehart and Winston. All rights reserved.

L

M

Index

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Index

Copyright © by Holt, Rinehart and Winston. All rights reserved.

N

O

Copyright © by Holt, Rinehart and Winston. All rights reserved.

P

Index

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

S

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Index

Copyright © by Holt, Rinehart and Winston. All rights reserved.

U

V

Copyright © by Holt, Rinehart and Winston. All rights reserved.

W

X

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Y

Z

Index

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Acknowledgments

continued from page ii

Academic Reviewers

continued

John Brockhaus, Ph.D.
Professor of Geospatial Information Science and Director of Geospatial Information Science Program
Department of Geography and Environmental Engineering
United States Military Academy
West Point, New York

Howard L. Brooks, Ph.D.
Professor of Physics and Astronomy
Department of Physics and Astronomy
DePauw University
Greencastle, Indiana

Dan Bruton, Ph.D.
Associate Professor
Department of Physics and Astronomy
Stephen F. Austin State University
Nacogdoches, Texas

Wesley N. Colley, Ph.D.
Lecturer
Department of Astronomy
University of Virginia
Charlottesville, Virginia

Jim Denbow, Ph.D.
Associate Professor of Archaeology
Department of Anthropology and Archaeology
The University of Texas at Austin
Austin, Texas

Turgay Ertekin, Ph.D.
Professor and Chairman of Petroleum and Natural Gas Engineering
Energy and Geo-Environmental Engineering
Pennsylvania State University
University Park, Pennsylvania

Simonetta Frittelli, Ph.D.
Associate Professor
Department of Physics
Duquesne University
Pittsburgh, Pennsylvania

Linda K. Gaul
Epidemiologist
Texas Department of Health
Austin, Texas

David Haig, Ph.D.
Professor of Biology
Organismic and Evolutionary Biology
Harvard University
Cambridge, Massachusetts

David S. Hall, Ph.D.
Assistant Professor of Physics
Department of Physics
Amherst College
Amherst, Massachusetts

Mary Kay Hemenway, Ph.D.
Research Associate and Senior Lecturer
Astronomy Department
The University of Texas at Austin
Austin, Texas

Richard N. Hey, Ph.D.
Professor of Geophysics
Department of Geophysics and Planetology
University of Hawaii at Manoa
Honolulu, Hawaii

Ken Hon, Ph.D.
Associate Professor of Volcanology
Geology Department
University of Hawaii at Hilo
Hilo, Hawaii

Susan Hough, Ph.D.
Scientist
United States Geological Survey (USGS)
Pasadena, California

William H. Ingham, Ph.D.
Professor of Physics
James Madison University
Harrisonburg, Virginia

Steven A. Jennings, Ph.D.
Associate Professor
Geography and Environmental Studies
University of Colorado at Colorado Springs
Colorado Springs, Colorado

David Lamp, Ph.D.
Associate Professor of Physics
Physics Department
Texas Tech University
Lubbock, Texas

Joel S. Leventhal, Ph.D.
Emeritus Scientist
United States Geological Survey (USGS)
Lakewood, Colorado

Mark Mattson, Ph.D.
Assistant Professor
Physics Department
James Madison University
Harrisonburg, Virginia

Madeline Micceri Mignone, Ph.D.
Assistant Professor
Natural Science
Dominican College
Orangeburg, New York

Richard F. Niedziela, Ph.D.
Assistant Professor of Chemistry
Department of Chemistry
DePaul University
Chicago, Illinois

Eva Oberdoerster, Ph.D.
Lecturer
Department of Biology
Southern Methodist University
Dallas, Texas

Sten Odenwald, Ph.D.
Astronomer
NASA Goddard Space Flight Center and Raytheon ITSS
Greenbelt, Maryland

Kenneth K. Peace
Manager of Transportation
WestArch Coal, Inc.
St. Louis, Missouri

H. Michael Sommermann, Ph.D.
Professor of Physics
Physics Department
Westmont College
Santa Barbara, California

Daniel Z. Sui, Ph.D.
Professor
Department of Geography
Texas A&M University
College Station, Texas

Vatche P. Tchakerian, Ph.D.
Professor
Department of Geography & Geology
Texas A&M University
College Station, Texas

Peter W. Weigand, Ph.D.
Professor Emeritus
Department of Geological Sciences
California State University
Northridge, California

Dwight L. Whitaker, Ph.D.
Assistant Professor of Physics
Department of Physics
Williams College
Williamstown, Massachusetts

Ross Whitwam, Ph.D.
Assistant Professor of Biology
Division of Science and Mathematics
Mississippi University for Women
Columbus, Mississippi

Lab Testing

Barry L. Bishop
Science Teacher and Department Chair
San Rafael Junior High
Ferron, Utah

Paul Boyle
Science Teacher
Perry Heights Middle School
Evansville, Indiana

Daniel Bugenhagen
Science Teacher and Department Chair
Yutan Junior–Senior High
Yutan, Nebraska

Alonda Droege
Biology Teacher
Evergreen High School
Seattle, Washington

Rebecca Ferguson
Science Teacher
North Ridge Middle School
North Richland Hills, Texas

Jennifer Ford
Science Teacher and Deptartment Chair
North Ridge Middle School
North Richland Hills, Texas

C. John Graves
Science Teacher
Monforton Middle School
Bozeman, Montana

Janel Guse
Science Teacher and Department Chair
West Central Middle School
Hartford, South Dakota

Dennis Hanson
Science Teacher and Dept. Chair
Big Bear Middle School
Big Bear Lake, California

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Norman Holcomb
Science Teacher
Marion Local Schools
Maria Stein, Ohio

Karma Houston-Hughes
Science Mentor
Kyrene Middle School
Tempe, Arizona

Tracy Jahn
Science Teacher
Berkshire Junior–Senior High
Canaan, New York

Kerry A. Johnson
Science Teacher
Isbell Middle School
Santa Paula, California

David Jones
Science Teacher
Andrew Jackson Middle School
Cross Lanes, West Virginia

Michael E. Kral
Science Teacher
West Hardin Middle School
Cecilia, Kentucky

Jason P. Marsh
Biology Teacher
Montevideo High School and Montevideo Country School
Montevideo, Minnesota

Edith C. McAlanis
Science Teacher and Department Chair
Socorro Middle School
El Paso, Texas

Kevin McCurdy, Ph.D.
Science Teacher
Elmwood Junior High School
Rogers, Arkansas

Alyson Mike
Science Teacher
East Valley Middle School
East Helena, Montana

Jan Nelson
Science Teacher
East Valley Middle School
East Helena, Montana

Dwight Patton
Science Teacher
Carrol T. Welch Middle School
Horizon City, Texas

Joseph Price
Science Teacher and Department Chair
H.M. Browne Junior High School
Washington, D.C.

Terry J. Rakes
Science Teacher
Elmwood Junior High
Rogers, Arkansas

Debra A. Sampson
Science Teacher
Booker T. Washington Middle School
Elgin, Texas

Helen Schiller
Instructional Coach
Greenville County Schools
Greenville, South Carolina

Bert Sherwood
Science Teacher
Socorro Middle School
El Paso, Texas

David M. Sparks
Science Teacher
Redwater Junior High School
Redwater, Texas

Larry Tackett
Science Teacher and Department Chair
Andrew Jackson Middle School
Cross Lanes, West Virginia

John Zambo
Science Teacher
Elizabeth Ustach Middle School
Modesto, California

Gordon Zibelman
Science Teacher
Drexel Hill Middle School
Drexel Hill, Pennsylvania

Teacher Reviewers

Barbara Gavin Akre
Teacher of Biology, Anatomy-Physiology, and Life Science
Duluth Independent School District
Duluth, Minnesota

Laura Buchanan
Science Teacher and Department Chairperson
Corkran Middle School
Glen Burnie, Maryland

Hilary Cochran
Science Teacher
Indian Crest Junior High School
Souderton, Pennsylvania

Karen Dietrich, S.S.J., Ph.D.
Principal and Biology Instructor
Mount Saint Joseph Academy
Flourtown, Pennsylvania

Randy Dye, M.S.
Middle School Science Department Head
Earth Science
Wood Middle School
Waynesville School District #6, Missouri

Trisha Elliott
Science and Mathematics Teacher
Chain of Lakes Middle School
Orlando, Florida

Liza M. Guasp
Science Teacher
Celebration K–8 School
Celebration, Florida

Meredith Hanson
Science Teacher
Westside Middle School
Rocky Face, Georgia

Ronald W. Hudson
Science Teacher
Batchelor Middle School
Bloomington, Indiana

James Kerr
Oklahoma Teacher of the Year 2002–2003
Oklahoma State Department of Education
Union Public Schools
Tulsa, Oklahoma

Laura Kitselman
Science Teacher and Coordinator
Loudoun Country Day School
Leesburg, Virginia

Deborah L. Kronsteiner
Teacher
Science Department
Spring Grove Area Middle School
Spring Grove, Pennsylvania

Jennifer L. Lamkie
Science Teacher
Thomas Jefferson Middle School
Edison, New Jersey

Sally M. Lesley
ESL Science Teacher
Burnet Middle School
Austin, Texas

Stacy Loeak
Science Teacher and Department Chair
Baker Middle School
Columbus, Georgia

Augie Maldonado
Science Teacher
Grisham Middle School
Round Rock, Texas

Alyson Mike
Science Teacher
East Valley Middle School
East Helena, Montana

Thomas Lee Reed
Science Teacher
Rising Starr Middle School
Fayetteville, Georgia

Shannon Ripple
Science Teacher
Science Department
Canyon Vista Middle School
Round Rock, Texas

Susan H. Robinson
Science Teacher
Oglethorpe County Middle School
Lexington, Georgia

Elizabeth Rustad
Science Teacher
Higley School District
Gilbert, Arizona

Helen Schiller
Instructional Coach
Greenville County Schools
Greenville, South Carolina

Mark Schnably
Science Instructor
Thomas Jefferson Middle School
Winston-Salem, North Carolina

Stephanie Snowden
Science Teacher
Canyon Vista Middle School
Round Rock, Texas

Marci L. Stadiem
Department Head
Science Department
Cascade Middle School, Highline School District
Seattle, Washington

Bruce A. Starek
Department Chairperson, Science Teacher
Baker Middle School
Michigan City, Indiana

Martha Tedrow
Science Teacher
Thomas Jefferson Middle School
Winston-Salem, North Carolina

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Martha B. Trisler
Science Teacher
Rising Starr Middle School
Fayetteville, Georgia

Florence Vaughan
Science Teacher
University of Chicago Laboratory Schools
Chicago, Illinois

Louise Whealton
Science Teacher
Wiley Middle School
Winston-Salem, North Carolina

Angie Williams
Teacher
Riversprings Middle School
Crawfordville, Florida

Roberta Young
Science Teacher
Gunn Junior High School
Arlington, Texas

Answer Checking

Hatim Belyamani
Austin, Texas

John A. Benner
Austin, Texas

Catherine Podeszwa
Duluth, Minnesota

Staff Credits

Editorial

Leigh Ann García, *Executive Editor*
Kelly Rizk, *Senior Editor*
David Westerberg, *Senior Editor*
Laura Zapanta, *Senior Editor*

Editorial Development Team

Karin Akre
Monica Brown
Jen Driscoll
Shari Husain
Michael Mazza
Karl Pallmeyer
Laura Prescott
Bill Rader
Jim Ratcliffe
Dennis Rathnaw
Betsy Roll
Kenneth Shepardson

Copyeditors

Dawn Marie Spinozza, *Copyediting Manager*
Simon Key
Jane A. Kirschman
Kira J. Watkins

Editorial Support Staff

Debbie Starr, *Managing Editor*
Kristina Bigelow
Suzanne Krejci
Shannon Oehler

Online Products

Bob Tucek, *Executive Editor*
Wesley M. Bain

Design

Book Design

Kay Selke, *Director of Book Design*
Mercedes Newman, *Page Designer*
Holly Whittaker, *Project Administrator*

Media Design

Richard Metzger, *Design Director*
Chris Smith, *Developmental Designer*

Image Acquisitions

Curtis Riker, *Director*
Jeannie Taylor, *Photo Research Manager*
Diana Goetting, *Senior Photo Researcher*
Elaine Tate, *Art Buyer Supervisor*
Angela Boehm, *Senior Art Buyer*

Publishing Services

Carol Martin, *Director*

Graphic Services

Bruce Bond, *Director*
Jeff Bowers, *Graphic Services Manager*
Katrina Gnader, *Graphics Specialist*
Cathy Murphy, *Senior Graphics Specialist*
Nanda Patel, *Graphics Specialist*
JoAnn Stringer, *Senior Graphics Specialist II*

Technology Services

Laura Likon, *Director*
Juan Baquera, *Technology Services Manager*
Lana Kaupp, *Senior Technology Services Analyst*
Margaret Sanchez, *Senior Technology Services Analyst*
Sara Buller, *Technology Services Analyst*
Patty Zepeda, *Technology Services Analyst*
Jeff Robinson, *Ancillary Design Manager*

New Media

Armin Gutzmer, *Director*
Melanie Baccus, *New Media Coordinator*
Lydia Doty, *Senior Project Manager*
Cathy Kuhles, *Technical Assistant*
Marsh Flournoy, *Quality Assurance Analyst*
Tara F. Ross, *Senior Project Manager*

Design New Media

Ed Blake, *Director*
Kimberly Cammerata, *Design Manager*
Michael Rinella, *Senior Designer*

Production

Eddie Dawson, *Production Manager*
Sherry Sprague, *Project Manager*
Suzanne Brooks, *Production Coordinator*

Teacher Edition

Alicia Sullivan
David Hernandez
April Litz

Manufacturing and Inventory

Jevara Jackson
Ivania Quant Lee
Wilonda Ieans

Ancillary Development and Production

General Learning Communications,
Northbrook, Illinois

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Credits

Abbreviations used: (t) top, (c) center, (b) bottom, (l) left, (r) right, (bkgd) background

PHOTOGRAPHY

Front Cover (tl) Andy Small/CORBIS; (tr) Andy Small/CORBIS; (b) Yva Momatiuk/ John Eastcott/Minden Pictures; (c) JH Carmicheal/Getty Images

Skills Practice Lab Teens Sam Dudgeon/HRW

Connection to Astrology Corbis Images; **Connection to Biology** David M. Phillips/ Visuals Unlimited; **Connection to Chemistry** Digital Image copyright © 2005 PhotoDisc; **Connection to Environment** Digital Image copyright © 2005 PhotoDisc; **Connection to Geology** Letraset Phototone; **Connection to Language Arts** Digital Image copyright © 2005 PhotoDisc; **Connection to Meteorology** Digital Image copyright © 2005 PhotoDisc; **Connection to Oceanography** © ICONOTEC; **Connection to Physics** Digital Image copyright © 2005 PhotoDisc

Table of Contents iii (t), Sam Dudgeon/HRW; iii (b), NASA; iv (t), Howard B. Bluestein; iv (bl), Tom Pantages Photography; v (t), E. R. Degginger/Color-Pic, Inc.; v (green), Dr. E.R. Degginger/Bruce Coleman Inc.; v (purple), Mark A. Schneider/Photo Researchers, Inc.; v, CORBIS Images/HRW; vi, Laurent Gillieron/Keystone/AP/Wide World Photos; vi (b), The G.R. "Dick" Roberts Photo Library; viii (t), National Geographic Image Collection/Robert W. Madden; viii (b), Bob Krueger/Photo Researchers, Inc.; ix (t), Glenn M. Oliver/Visuals Unlimited; ix (b) Tom Bean/CORBIS; x (t), Stuart Westmorland/CORBIS; xi (t), Goddard Space Flight Center Scientific Visualization Studio/NASA; xi (b), NASA; xii (tl), Index Stock; xii (c), MSFC/NASA; xii (bl), Peter Van Steen/HRW; xiii (t), Bill & Sally Fletcher/Tom Stack & Associates; xiii (b), NASA/TSADO/Tom Stack & Associates; xiv (t), NASA/Peter Arnold, Inc.; xv; Sam Dudgeon/HRW; xvi, Victoria Smith/HRW; xviii, xix, xx, xxii, Victoria Smith/HRW; xxvi, Sam Dudgeon/HRW; xxvii (t), John Langford/HRW; xxvii (b), xxviii (t, bl), Sam Dudgeon/HRW; xxviii (bl), Stephanie Morris/HRW; xxix (tl), Sam Dudgeon/HRW; xxix (tr), Jana Birchum/HRW; xxix (b), Sam Dudgeon/HRW

Chapter One 4 Peter Van Steen/HRW Photo; 5 (t) Peter Van Steen/HRW; 5 (b) Victoria Smith/HRW; 7(t) Mike Segar/Reuters Photo Archive; 7(b) CORBIS/ Annie Griffiths Belt; 8 (t) Annie Griffiths/Westlight/Corbis; 8 (b) AP Photo/Knoxville News-Sentinel; 9 Aurora Photos; 11 Peter Van Steen/HRW; 12 Courtesy of Dr. David Gillette; 16 Paul Fraughton/HRW; 18 (l) Sam Dudgeon/HRW; 18 (r) Jim Sugar Photography/CORBIS; 20 (l) AKG-Images; 20 (r) Image Copyright ©2001 PhotoDisc, Inc.; 21 Victoria Smith/HRW; 22 CENCO; 22 (zoom) Robert Brons/Getty Images/ Stone; 23 Victoria Smith/HRW; 25 (t) (b) Peter Van Steen/HRW; 26 (l) Peter Van Steen/HRW; 26 (r) Peter Van Steen/HRW; 30 Paul Fraughton/HRW 31 (R) Image Copyright ©2001 PhotoDisc, Inc.34 (tr), The Stuart News, Carl Rivenbark/AP/Wide World Photos; 35, AFP/CORBIS; 35 (b), AFP/CORBIS

Unit One 36 (tl), Charles Scribner's Sons NY, 1506; 36 (bl), USGS/NASA/Science Source/Photo Researchers, Inc.; 37 (tl), Getty Images/Taxi; 37 (tr), Culver Pictures Inc.; 37 (c), Lambert/Hulton Archive/Getty Images; 37 (cr), Steve Winter/National Geographic Society; 37 (cl), Randy Duchaine/Corbis Stock Market; 37 (b), Robotics Institute Carnegie Mellon University

Chapter Two 38-39, Terry Wilson; 40, Sam Dudgeon/HRW; 41, Dr. Rainer Bode/ Bode-Verlag Gmb; 42 (tr), Victoria Smith/HRW; 42 (bc), Sam Dudgeon/HRW; 42 (tl), Sam Dudgeon/HRW; 43, (copper), E. R. Degginger/Color-Pic, Inc.; 43, (calcite), E. R. Degginger/Color-Pic, Inc.; 43, (fluorite), E. R. Degginger/Color-Pic, Inc.; 43, (corundum), E. R. Degginger/Color-Pic, Inc.; 43, (gypsum), SuperStock; 43, (galena), Visuals Unlimited/Ken Lucas; 39, (vitreous), Biophoto Associates/Photo Researchers, Inc.; 39, (waxy), Biophoto Associates/Photo Researchers, Inc.; 39, (silky), Dr. E.R. Degginger/ Bruce Coleman Inc.; 39, (submetallic), John Cancalosi 1651/DRK Photo; 39 (bl), Kosmatsu Mining Systems; 39, (resinous), Charles D. Winters/Photo Researchers, Inc.; 39, (pearly), Victoria Smith/HRW; 39, (metallic), Victoria Smith/HRW; 39, (earthy), Sam Dudgeon/HRW; 40 (tr, c, bl), Sam Dudgeon/HRW; 40, Tom Pantages; 46, (1), Visuals Unlimited/Ken Lucas; 46, (3), Visuals Unlimited/Dane S. Johnson; 46, (7), Carlyn Iverson/Absolute Science Illustration and Photography; 46, (8), Mark A. Schneider/Visuals Unlimited; 46, (9), Charles D. Winters/Photo Researchers, Inc.; 46, (10), Bard Wrisley; 46, (5), Biophoto Associates/Photo Researchers, Inc.; 46, (6), Victoria Smith/HRW; 46, (4), Mark A. Schneider/Photo Researchers, Inc.; 46, (2), Sam Dudgeon/HRW; 47 (tc), Sam Dudgeon/HRW; 47 (tr), Sam Dudgeon/HRW, Courtesy Science Stuff, Austin, TX; 47 (br), Tom Pantages Photography; 47 (bc), Sam Dudgeon/ HRW; 47 (tl), Mark A. Schneider/Photo Researchers, Inc.; 47 (tl), Mark A. Schneider/ Photo Researchers, Inc.; 47 (bl), 48 (t), Sam Dudgeon/HRW; 48 (bl), Victoria Smith/ HRW Photo, Courtesy Science Stuff, Austin, TX; 48 (c), Breck P. Kent; 49 (br), Sam Dudgeon/HRW; 49 (c), Breck P. Kent; 49 (t), Visuals Unlimited/Ken Lucas; 50 (br), Wernher Krutein; 51, Stewart Cohen/Index Stock Photography, Inc.; 52, Digital Image copyright © 2005 PhotoDisc; 53, Historic Royal Palaces; 54 (c), Russell Dian/HRW; 54 (b), 55 (tr), Sam Dudgeon/HRW; 56, Digital Image copyright © 2005 PhotoDisc; 57 (b), E. R. Degginger/Color-Pic, Inc.; 60 (t), Stephan Edelbroich; 61 (t), Will & Dennie McIntyre/McIntyre Photography; 61 (b), Mark Schneider/Visuals Unlimited

Chapter Three 62-63, Tom Till; 64 (bl), Michael Melford/Getty Images/The Image Bank; 64 (br), Joseph Sohm; Visions of America/CORBIS; 65, CORBIS Images/HRW; 68 (t), Joyce Photographics/Photo Researchers, Inc.; 68 (l), Pat Lanza/Bruce Coleman Inc.; 68 (r), Sam Dudgeon/HRW ; 68 (b), James Watt/Animals Animals/Earth Scenes; 68 (l), Pat Lanza/Bruce Coleman Inc.; 69, (granite), Pat Lanza/Bruce Coleman Inc.; 69, (mica), E. R. Degginger/Color-Pic, Inc.; 69, (aragonite), Breck P. Kent; 69, (limestone), Breck P. Kent; 69, (calcite), Mark Schneider/Visuals Unlimited; 69, (feldspar), Mark Schneider/Visuals Unlimited; 69, (quartz), Digital Image copyright © 2005 PhotoDisc; 70 (tl), Sam Dudgeon/HRW; 70 (tc), Dorling Kindersley; 70 (tr, br), Breck P. Kent; 70 (bl), E. R. Degginger/Color-Pic, Inc.; 71, Joseph Sohm; Visions of America/ CORBIS; 72 (l), E. R. Degginger/Color-Pic, Inc.; 73 (tr, tl, bl), Breck P. Kent; 73 (br), Victoria Smith/HRW; 75, J.D. Griggs/USGS; 76, CORBIS Images/HRW; 77, (conglomerate), Breck P. Kent; 77, (siltstone), Sam Dudgeon/HRW; 77, (sandstone), Joyce Photographics/Photo Researchers, Inc.; 77, (shale), Sam Dudgeon/HRW; 78 (tl), Stephen Frink/Corbis; 78 (br), Breck P. Kent; 78 (bc), David Muench/CORBIS; 79, Franklin P. OSF/Animals Animals/Earth Scenes; 80, George Wuerthner; 82, (calcite), Dane S. Johnson/Visuals Unlimited; 82, (quartz), Carlyn Iverson/Absolute Science Illustration and Photography; 82, (hematite), Breck P. Kent; 82, (garnet), Breck P. Kent/Animals Animals/Earth Scenes; 82, (chlorite), Sam Dudgeon/HRW; 82, (mica), Tom Pantages; 83, (shale), Ken Karp/HRW; 83, (slate), Sam Dudgeon/HRW; 83, (phyllite), Sam Dudgeon/HRW; 83, (gneiss), Breck P. Kent; 83, (schist), Sam Dudgeon/HRW; 84 (tl), E. R. Degginger/Color-Pic, Inc.; 84 (bl), Ray Simmons/Photo Researchers, Inc; 84 (tr), The Natural History Museum, London; 84 (br), Breck P. Kent; 85, Jim Wark/Airphoto; 87 (t), Sam Dudgeon/HRW; 87 (b), James Tallon; 92 (l), Wolfgang Kaehler/CORBIS; 92 (tr), Dr. David Kring/Science Photo Library/Photo Researchers, Inc.; 93 (r), James Miller/Courtesy Robert Folk, Department of Geological Sciences, University of Texas at Austin; 93 (l), Dr. Philppa Uwins, Whistler Research PTY/SPL/Photo Researchers, Inc.; 94 (inset), Roger Ressmeyer/CORBIS

Chapter Four 94-95, James Balog/Getty Images/Stone; 97 (t), James Wall/Animals Animals/Earth Scenes; 100, Bruce C. Heezen and Marie Tharp; 111 (tc), ESA/CE/ Eurocontrol/Science Photo Library/Photo Researchers, Inc.; 111 (tr), NASA; 376 (bl, br), Peter Van Steen/HRW; 113 (bc), Visuals Unlimited/SylvesterAllred; 113 (br), G.R. Roberts Photo Library; 115 (tl), Tom Bean; 115 (tr), Landform Slides; 116, Jay Dickman/CORBIS; 117 (b), Michele & Tom Grimm Photography; 118, Y. Arthus-B./ Peter Arnold, Inc.; 119, Peter Van Steen/HRW; 121, Sam Dudgeon/HRW; 126 (bl), NASA/Science Photo Library/Photo Researchers, Inc.; 126 (c), Ron Miller/Fran Heyl Associates; 126 (tr), Photo by S. Thorarinsson/Solar-Filma/Sun Film-15/3/courtesy of Edward T. Baker, Pacific Marine Environmental Laboratory, NOAA; 127 (r), Bettman/ CORBIS

Chapter Five 128-129, Robert Patrick/Sygma/CORBIS; 131, Roger Ressmeyer/ CORBIS; 137, Earth Images/Getty Images/Stone; 139, Bettmann/CORBIS; 142, Michael S. Yamashita/CORBIS; 144, Paul Chesley/Getty Images/Stone; 146, NOAA/ NGDC; 147, Sam Dudgeon/HRW; 149, Bettmann/CORBIS; 152, Sam Dudgeon/HRW; 152 (t), Courtesy Stephen H. Hickman, USGS; 153 (t), Todd Bigelow/HRW; 153 (b), Corbis Images

Chapter Six 154-155, Carl Shaneff/Pacific Stock; 156 (bl), National Geographic Image Collection/Robert W. Madden; 156 (br), Ken Sakamoto/Black Star; 157 (b), Breck P. Kent/Animals Animals/Earth Scenes; 157, Joyce Warren/USGS Photo Library; 159 (tl), Tui De Roy/Minden Pictures; 159 (bl), B. Murton/Southampton Oceanography Centre/Science Photo Library/Photo Researchers, Inc.; 159 (tr), Visuals Unlimited/Martin Miller; 159 (br), Buddy Mays/CORBIS; 160 (tr), Tom Bean/DRK Photo; 160 (tl), Francois Gohier/Photo Researchers, Inc.; 160, (tlc), Visuals Unlimited Inc./Glenn Oliver; 160, (tlb), E. R. Degginger/Color-Pic, Inc.; 161 (tr), Alberto Garcia/ SABA/CORBIS; 161, Robert W. Madden/National Geographic Society; 162, Images & Volcans/Photo Researchers, Inc.; 163 (br), SuperStock; 163 (cr), SuperStock; 163 (tr), Roger Ressmeyer/CORBIS; 164 (tl), Yann Arthus-Bertrand/CORBIS; 165, Joseph Sohm; ChromoSohm Inc./CORBIS; 618 (bl), Robert McGimsey/USGS Alaska Volcano Observatory; 622 (tr), Alberto Garcia/SABA/CORBIS; 178 (bl), CORBIS; 178 (tr), Photo courtesy of Alan V. Morgan, Department of Earth Sciences, University of Waterloo; 178 (tc), © Sigurgeir Jonasson; Frank Lane Picture Agency/CORBIS; 179 (bl), Courtesy Christina Neal; 179 (r), Courtesy Alaska Volcano Observatory

Unit Two 180 (bl), Detail of The Age of Reptiles, a mural by Rudolph F. Zallinger. ©1996, 1975,1985,1989, Peabody Museum of Natural History, Yale University, New Haven, Connecticut, USA.; 180-181 (bc), Price, R.-Survi OSF/Animals Animals/Earth Scenes; 181 (c), Peter Essick/Aurora; 188 (bl), Tom Bean/CORBIS; 181 (tr), John Eastcott/YVA Momatiuk/DRK Photo; 181(cl), Stock Montage, Inc.; 181 (cr), Tom Bean/Getty Images/Stone; 181 (br), Hong Kong Airport Authority/AP/Wide World Photos; 181 (inset), Corbis Images

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Chapter Seven 182-183, Johny Sundby/Zuma Press/NewsCom; 184, SuperStock; 185 (tc), Visuals Unlimited/Martin G. Miller; 185 (tl), Ron Niebrugge/Niebrugge Images; 186 (tr), Grant Heilman/Grant Heilman Photography; 187 (t), John Sohlden/ Visuals Unlimited; 188 (t), Laurence Parent; 188 (b), C. Campbell/Westlight/Corbis; 426, Bob Krueger/Photo Researchers, Inc.; 189 (b), B. Ross/Westlight/Corbis; 192 (bl), Digital Image copyright © 2005 EyeWire ; 192 (br), David Cumming; Eye Ubiquitous/CORBIS; 193, Corbis Images; 194, The G.R. "Dick" Roberts Photo Library; 198, Tom Bean/Getty Images/Stone; 199 Bill Ross/Westlight/Corbis; 200 (t), Bruce Coleman, Inc.; 200, (b) Lee Rentz/Bruce Coleman, Inc.; 201, Tom Bean/Getty Images/Stone; 202 (bl), Grant Heilman Photography, Inc.; 202 (br), Charlton Photos, Inc.; 204, Kevin Fleming/CORBIS; 205 (r), Mark Lewis/ImageState; 205 (l), Paul Chesley/Getty Images/Stone; 206, (t) Bettmann/CORBIS; 206 (b) Tom Hovland/Grant Heilman Photography, Inc.; 207 (b), AgStockUsa; 208 (bl), 209 Sam Dudgeon/HRW; 210, B. Ross/Westlight/Corbis; 211, Bob Krueger/Photo Researchers, Inc.; 214 (tr), M.A. Kessler/Earth Sciences Department, University of California at Santa Cruz; 214 (tl), © W. Ming/UNEP/Peter Arnold, Inc.; 215 (t), Michael Murphy/By permission of Selah, Bamberger Ranch; 215 (b), Michael Murphy/By permission of Selah, Bamberger Ranch

Chapter Eight 216-217, John Kuntz/Reuters NewMedia Inc./CORBIS; 218, Aaron Chang/Corbis Stock Market; 219 (t), Tom Bean; 219 (b), CORBIS Images/HRW; 220 (tc), The G.R. "Dick" Roberts Photo Library; 220 (br), Jeff Foott/DRK Photo; 220 (bl), CORBIS Images/HRW; 221 (tl), Breck P. Kent; 221 (tr), John S. Shelton ; 222 (t), Don Herbert/Getty Images/Taxi; 222 (b), Jonathan Weston/ImageState; 222 (t), SuperStock; 223, InterNetwork Media/Getty Images; 225, Jonathan Blair/CORBIS; 230, Telegraph Colour Library/FPG International/Getty Images/Taxi; 232, Tom Bean/ CORBIS; 234 (b), Getty Images/Stone; 234 (t), Visuals Unlimited/Glenn M. Oliver; 236, 237, Tom Bean; 236 (b), Mike Yamashita/Woodfin Camp & Associates; ; 236 (t), Jebb Harris/Orange County Register/SABA/CORBIS;237, Visuals Unlimited/John D. Cunningham; 238 (l), Sam Dudgeon/HRW; 238 (r), Sam Dudgeon/HRW Photo; 239 (b), Sebastian d'Souza/AFP/CORBIS; 239 (t), Jacques Jangoux/Getty Images/Stone 238, Sam Dudgeon/HRW; 240, Tom Bean/CORBIS; 241, Aaron Chang/Corbis Stock Market

Unit Three 246 (t), Astronomical Society of Pacific/Peter Arnold, Inc; 246 (c), Warren Faidley/NASA/Image State; 246 (bl), NASA/JPL; 247 (tl), Alfred Pasieka/Peter Arnold, Inc.; 247 (tr), Hulton Archive/Getty Images; 247 (cl, bc), NASA; 247 (cr), NASA/JPL; 247 (paper), Hulton Archive/Getty Images

Chapter Nine 248-249 Corbis; 250 (bc), Scott Van Osdol/HRW; 611(r) John Bova/ Photo Researchers, Inc.; 611 (tr) John Bova/Photo Researchers, Inc.; 611 (tc) John Bova/Photo Researchers, Inc.; 611 (tl) John Bova/Photo Researchers, Inc.; 611 (l) John Bova/Photo Researchers, Inc.; 611 (bl) John Bova/Photo Researchers, Inc.; 611 (bc) John Bova/Photo Researchers, Inc.; 611 (br) John Bova/Photo Researchers, Inc.; 612 (c) Fred Espenak; 613 (l) Jerry Lodriguss/Photo Researchers, Inc.; 265 (tl), VOSCAR/The Maine Photographer; 265 (tr), VOSCAR/The Maine Photographer; 268, NASA; ; 272 (b), NSO/NASA; 272 (tr), Jon Lomberg/Science Photo Library/ Photo Researchers, Inc.; 272 (inset), David A. Hardy/Science Photo Library/Photo Researchers, Inc.; 273 (r), NASA/CXC/SAO/AIP/Niels Bohr Library; 273 (l), Corbis Sygma

Chapter Ten 274-275, Anglo-Australian Observatory/Royal Obs. Edinburgh; .; 277 (tl), Jim Cummings/Getty Images/Taxi; 277 (tc), Mike Yamashita/Woodfin Camp/Picture Quest; 277 (tr), NASA; 277 (cr), Nozomi MSI Team/ISAS; 277 (bc), Jerry Lodriguss/ Photo Researchers, Inc.; 277 (br), Tony & Daphne Hallas/Science Photo Library/Photo Researchers, Inc.; 278 (t) Time Life Pictures/Getty Images; 278, (b) Bill & Sally Fletcher/Tom Stack & Associates; 282 (br), Dennis Di Cicco/Peter Arnold, Inc.; 282 (bl), David Malin/Anglo-Australian Observatory; 283 (bl), I M House/Getty Images/ Stone; 283 (br), Bill &Sally Fletcher/Tom Stack & Associates; 283 (bc), Jerry Lodriguss/Photo Researchers, Inc; 284, NASA/CXC/Smithsonian Astrophysical Observatory; ; 285, David Malin/Anglo-Australian Observatory/Royal Observatory, Edinburgh; 290, NASA/Mark Marten/Photo Researchers, Inc. ; 291, NASA/TSADO/Tom Stack & Associates; 292, Earth Imaging/Getty Images/Stone; 295, SuperStock; 296 (l), Breck P. Kent/Animals Animals/Earth Scenes; 296 (r), John Reader/Science Photo Library/Photo Researchers, Inc; 298, Sam Dudgeon/HRW; 300, Earth Imaging/Getty Images/Stone; 304 (b), NSO/NASA; 304 (tr), Jon Lomberg/Science Photo Library/ Photo Researchers, Inc.; 304 (inset), David A. Hardy/Science Photo Library/Photo Researchers, Inc.; 305 (r), NASA/CXC/SAO/AIP/Niels Bohr Library; 305 (l), Corbis Sygma

Chapter Eleven 306-307, NASA/CORBIS; 308 (Mercury), NASA; 308 (Venus), NASA/ Peter Arnold, Inc; 308 (Earth), Paul Morrell/Getty Images/Stone; 308 (Mars), USGS/ TSADO/Tom Stack & Associates; 308 (Jupiter), Reta Beebe (New Mexico State University)/NASA; 312, NASA/Mark S. Robinson; 313, NASA; 314 (b), NASA; 314 (tl), Frans Lanting/Minden Pictures; 315, World Perspective/Getty Images/Stone; 315 (b), 316 (b), 316 (inset), NASA; 317, ESA; 318, NASA/Peter Arnold, Inc.; 319 (t), 319 (br), 319 (Saturn), 319 (Uranus), 319, (Neptune), 319 (Pluto), 320 (t), 321, 322 (t), 324, NASA; 326 (moons), John Bova/Photo Researchers, Inc.; 327 David A. Hardy/Science Photo Librarye; 331, Bill & Sally Fletcher/Tom Stack & Associates; 331 (bc), Breck P. Kent/Animals Animals/Earth Scenes; 331 (bl), E.R. Degginger/Bruce Coleman Inc.; 331 (br), Ken Nichols/Institute of Meteorites/University of New Mexico; 331 (t), Dennis Wilson/Science Photo Library/Photo Researhers, Inc.; 332, NASA; 333, Ken Nichols/Institute of Meteorites/University of New Mexico; 336, NASA; 337, ESA; 337 (b), NASA; 340 (tr), Richard Murrin; 341 (t), NASA; 341 (bl), Mehau Kulyk/Science Photo Library/Photo Researchers, Inc.

Chapter Twelve 342, Smithsonian Institution/Lockhead Corportation/Courtesy of Ft. Worth Museum of Science and History; 344, NASA; 345 (tr), Hulton Archive/Getty Images; 348 (bl), Brian Parker/Tom Stack & Associates; 348 (br), Sam Dudgeon/ HRW; 350, Aerial Images, Inc. and SOVINFORMSPUTNIK; 351, NASA Marshall/ National Space Science and Technology Center; 352 (bl, br), USGS; 354 (bkgd), Jim Ballard/Getty Images/Stone; 355 (bl), JPL/TSADO/Tom Stack & Associates; 355 (bkgd), Jim Ballard/Getty Images/Stone; 356 (bkgd), Jim Ballard/Getty Images/Stone; 356 (b), NASA/JPL/Malin Space Station Systems; 357 (bkgd), Jim Ballard/Getty Images/Stone; 359, JPL/NASA; 360 (bl, br), Bettmann/CORBIS; 361 (t), NASA; 361 (br), Corbis Images; 362 (plane), NASA; 362 (bkgd), Telegraph Colour Library/Getty Images/Taxi; 363, NASA; 364 (b), JPL/NASA; 365 (t) Alamy; 365 (l) Bettman/CORBIS 365 (r) CORBIS/ Chuck Savage; 366 (bl) Royalty-Free/CORBIS 366 (br) LWA- Stephen Welstead/CORBIS ; 367Corbis; 374 (bl), NASA; 374 (tr), Photo courtesy Robert Zubrin, Mars Society; 375 (tr, b), NASA

Unit Four 376 (t), The Granger Collection, New York; 376 (c), Corbis-Bettmann; 376 (br), Conley Photography, Inc./American Solar Energy Society; 377 (tr), Phil Degginger/Color-Pic, Inc.; 377 (cl), Robert Wolf/HRW; 377 (c), The Granger Collection, New York; 377 (bc), David Madison; 377 (br), Courtesy of DEKA Research and Development/PRNewsFoto/NewsCom

Chapter Thirteen 378-379 (all), © AFP/CORBIS; 380 (br), Tim Kiusalaas/Masterfile; 381 (cr), Sam Dudgeon/HRW; 382 (tl), Earl Kowall/CORBIS; 383 (br), Sam Dudgeon/ HRW; 384 (tl), John Langford/HRW; 384 (tc), Corbis Images; 384 (tr), David Phillips/ HRW; 385 (br), Sam Dudgeon/HRW; 385 (cr), Peter Van Steen/HRW; 386 (tr), John Langford/HRW; 386 (bl), NASA; 387 (cr), Peter Van Steen/HRW; 388 (br), © Duomo/ CORBIS; 389 (bl, br), John Langford/HRW; 389 (tr), Peter Van Steen/HRW; 392 (all), John Langford/HRW; 393 (tr), © Martin Bond/Photo Researchers, Inc.; 396 (bl), Sam Dudgeon/HRW; 397 (all), Courtesy of Honda; 399 (tl), Robert Brook/Photo Researchers, Inc.; 399 (cl), Sam Dudgeon/HRW; 399 (bl), John Langford/HRW; 400 (bl), D.O.E./Science Source/Photo Researchers, Inc.; 401 (tr), © John D. Cunningham/ Visuals Unlimited; 401 (b), CORBIS Images/HRW; 402 (tl), Digital Image copyright © 2005 PhotoDisc; 406 (tl), Courtesy of Honda; 406 (bc), Digital Image copyright © 2005 PhotoDisc; 407 (bl), Mike Powell/Allsport/Getty Images; 410 (bl), Courtesy Pursuit Dynamics; 410 (tr), © Bettman/CORBIS; 411 (all), Robert Wolf/HRW

Chapter Fourteen 412-413 (all), © Vandystadt/Allsport/Getty Images; 415 (br), John Langford/HRW; 417 (br), Michelle Bridwell/HRW; 418 (tl), Mark Burnett/Photo Researchers, Inc.; 419 Foodpix/Getty; 420 (b) Mark Gibson Photography; 421 (tl), Mark Burnett/Photo Researchers, Inc.; 422 (tr), AP Photo/Joe Giblin; 423 (all), Sam Dudgeon/HRW; 324 Photo Researchers/Science Photo Library 425 (b), John Langford/HRW; 327 David A. Hardy/Science Photo Library; 428 (tr), Sam Dudgeon/ HRW; 429 (tl), John Langford/HRW; 431 (br), Victoria Smith/HRW; 432 (tl), John Langford/HRW; 433 (bl), AP Photo/Joe Giblin; 436 (tl), Dan Winters/Discover Magazine; 437 (b), Solar Survival Architecture; 437 (tr), Singeli Agnew/Taos News

Unit Five 438 (c), Photofest; 438 (bl), Hughes Research Laboratories; 438 (br), Sam Dudgeon/HRW; 438 (tr), © Archivo Iconografico, S.A./CORBIS; 439 (tl), David Parker/ Science Photo Library/Photo Researchers, Inc.; 439 (tr), Dr. E.R. Degginger; 439 (cr), Fotos International/Hulton Archive/Getty Images; 439 (bl), Victoria Smith/HRW; 439 (br), Kieran Doherty/REUTERS/NewsCom

Chapter Fifteen 440-441 (all), © Jason Childs/Getty Images; 443 (tr), Robert Mathena/Fundamental Photographs, New York; 443 (bl), © Albert Copley/Visuals Unlimited; 444 (t), NASA; 451 (tr), © Steve Kaufman/CORBIS; 452 (br), Erich Schrempp/Photo Researchers, Inc.; 453 (tl), Richard Megna/Fundamental Photographs; 454 (tc), Educational Development Center; 456 (tl), Richard Megna/ Fundamental Photographs; 456 (bl), John Langford/HRW; 458 (br), James H. Karales/ Peter Arnold, Inc.; 459 (b), Sam Dudgeon/HRW; 460 (bl), Richard Megna/ Fundamental Photographs; 461 (bl), Martin Bough/Fundamental Photographs; 464 (tl), Pete Saloutos/The Stock Market; 464 (tr), The Granger Collection, New York; 465 (all), Peter Van Steen/HRW

Copyright © by Holt, Rinehart and Winston. All rights reserved.

Chapter Sixteen 466-467 (all), © Flip Nicklin/Minden Pictures; 469 (tl), John Langford/HRW; 470 (tr), Sam Dudgeon/HRW; 472 (tr), Sam Dudgeon/HRW; 473 (tr), Mary Kate Denny/PhotoEdit; 474 (all), Archive Photos; 476 (t), John Langford/HRW; 477 (bl), John Langford/HRW; 479 (tr), Charles D. Winters; 481 (t), © Stephen Dalton/Photo Researchers, Inc.; 482 (tl), Matt Meadows/Photo Researchers, Inc.; 484 (all), Richard Megna/Fundamental Photographs; 539 (tr), Sam Dudgeon/HRW; 486 (bc), Sam Dudgeon/HRW; 487 (bl), Digital Image copyright © 2005 EyeWire ; 487 (br), John Langford/HRW; 488 (tr, tl), Digital Image copyright © 2005 EyeWire ; 488 (bc), Bob Daemmrich/HRW; 490 (bl), Richard Megna/Fundamental Photographs; 491 (br), Sam Dudgeon/HRW; 492 (tl), © Flip Nicklin/Minden Pictures; 492 (bc), Sam Dudgeon/HRW; 493 (tc), © Ross Harrison Koty/Getty Images; 493 (cl), Dick Luria/ Photo Researchers, Inc.; 493 (br), John Langford/HRW; 497 (all), Victoria Smith/HRW

Chapter Seventeen 498-499 (all), Matt Meadows/Peter Arnold, Inc.; 501 (tl), Charlie Winters/Photo Researchers, Inc.; 501 (tr), Richard Megna/Fundamental Photographs; 502 (t), © A.T. Willett/Getty Images; 503 (tr), © Detlev Van Ravenswaay/Photo Researchers, Inc.; 595 (br), © Darwin Dale/Photo Researchers, Inc.; 506 (bl), Sovfoto/Eastfoto; 507 (bl), Richard Megna/Fundamental Photographs; 509 (br), Ken Kay/Fundamental Photographs; 511 (cr), Ken Kay/Fundamental Photographs; 602 (br), Stephanie Morris/HRW; 513 (all), John Langford/HRW; 514 (tl), Image copyright ©1998 PhotoDisc, Inc.; 514 (tr), Renee Lynn/Davis/Lynn Images; 514 (bl), Robert Wolf/HRW; 605 (tl), Leonard Lessin/Peter Arnold, Inc.; 516 (br), Sam Dudgeon/HRW; 517 (t), Index Stock Photography, Inc.; 517 (cr), Peter Van Steen/HRW; ; 520 (tl), © Digital Vision Ltd.; 520 (tr), Courtesy www.vischeck.com (program)/©Digital Vision Ltd. (frogs); 521 (tr), © Yoav Levy/Phototake; 523 (tr), Sam Dudgeon/HRW; 524 (br), Matt Meadows/Peter Arnold, Inc.; 524 (tl), Image copyright © 2005 PhotoDisc, Inc.; 525 (cr), Charles D. Winters/Photo Researchers, Inc.; 525 (bcr), © Mark E. Gibson; 525 (br), Richard Megna/Fundamental Photographs; 528 (tl), Dr. E. R. Degginger; 528 (tr), courtesy of the Raytheon Company; 529 (cr), © Underwood & Underwood/ CORBIS

Unit Six 530 (t), Carr Clifton/Minden Pictures; 530 (c), Getty Images/FPG International; 530 (b), Tom Brakefield/Corbis; 531 (tr), Photo Researchers; 531 (cr), SuperStock; 531 (bl), © David Young Wolff/Getty Images/Stone; 531 (cl), Alfred Eisenstaedt/Life Magazine © Time Inc.; 531 (br), © James Watt/Visuals Unlimited; 531 (tl), © Tony Hamblin/CORBIS

Chapter Eighteen 532-533 © Roine Magnusson/Getty Images/The Image Bank; 539 (r), © David M. Phillips/Visuals Unlimited; 541 (t), © George H. H. Huey/ CORBIS; 541 (c), © D. Robert & Lorri Franz/CORBIS; 541 (b), © Jason Brindel Photography/Alamy Photos; 542 (t), Laguna Photo/Liaison International/Getty News Images; 542 (b), Jeff Lepore/Photo Researchers; 544 Jeff Foott/AUSCAPE; 545 © Ross Hamilton/Getty Images/Stone; 546 (l), Visuals Unlimited/Gerald & Buff Corsi; 546 (cr), Hans Pfletschinger/Peter Arnold; 547 (r), W. Peckover/Academy of Natural Sciences Philadelphia/VIREO; 547 (l), Leroy Simon/Visuals Unlimited; 548 (b), Ed Robinson/Tom Stack & Associates; 548 (tl), © Telegraph Color Library/Getty Images/ FPG International; 548 (tr), OSF/Peter Parks/Animals Animals Earth Scenes; 549 (t), © Gay Bumgarner/Getty Images/Stone; 549 (b), Carol Hughes/Bruce Coleman; 550 (tl), CSIRO Wildlife & Ecology; 550 (r), © Rick & Nora Bowers/Visuals Unlimited; 551 Leroy Simon/Visuals Unlimited; 558 (r), © National Geographic Image Collection/ Darlyne Murawski; 558 (l), Digital Image copyright © 2005 PhotoDisc; 559 (r), Photo from the Dept. of Communication Services, North Carolina State University; 559 (l), Digital Image copyright © 2005 Artville

Chapter Nineteen 560-561 © Bryan and Cherry Alexander Photography; 566 (l), Diana L. Stratton/Tom Stack & Associates; 566 (r), © Stan Osolinski; 569 Kim Heacox/DRK Photo; 572 (l), Dr. Jeremy Burgess/Science Photo Library/Photo Researchers; 574 Hardie Truesdale/International Stock/ImageState; 575 (t) Leonard Lee Rue/Photo Researchers; 575 (b) Richard Hamilton Smith/CORBIS; 576 John Warden/Index Stock Imagery/Picturequest; 577 Robert Brons/Biological Photo Service; 578 (t) G.R. Roberts Photo Library; 578 (zoom) C.P. Vance/Visuals Unlimited; 580 Sam Dudgeon/HRW; 581 (br), Sam Dudgeon/HRW; 581 (bl), Sam Dudgeon/ HRW; 581 (t), Sam Dudgeon/HRW; 586 (t), Reed Saxon/AP/Wide World Photos; 587 (t), Neil Michel/Axiom; 587 (b), Neil Michel/Axiom

Chapter Twenty 588-589 Martin Harvey/NHPA; 590 Larry Lefever/Grant Heilman Photography; 591 (t), J. Roche/Peter Arnold, Inc.; 591 (b), NASA; 592 (b), © Jacques Jangoux/Getty Images/Stone; 593 Alamy; 594 © Rex Ziak/Getty Images/Stone; 595J. Roche/Peter Arnold, Inc.; 596 (l), Peter Van Steen/HRW; 596 (c), Peter Van Steen/ HRW; 596 (r), Peter Van Steen/HRW; 597 (t), Argonne National Laboratory; 597 (b), Digital Image copyright © 2005 PhotoDisc; 598 (b), PhotoEdit; 598 (t), Kay Park-Rec Corp.; 599 (t), Peter Van Steen/HRW; 599 (b), Martin Bond/Science Photo Library/ Photo Researchers; 600 (b), K. W. Fink/Bruce Coleman; 600 (t), © Sindre Ellingsen/ Alamy Photos; 601 Stephen J. Krasemann/DRK Photo; 602 (bl), Sam Dudgeon/HRW; 602 (t), © Will & Deni McIntyre/Getty Images/Stone; 602 (br), Stephen J. Krasemann/DRK Photo; 603 (t), K. W. Fink/Bruce Coleman; 604 Peter Van Steen/ HRW; 605 (tl), Tom Bean/DRK Photo; 605 (tr), Darrell Gulin/DRK Photo; 606 (l), Peter Van Steen/HRW; 606 (r), Peter Van Steen/HRW; 607 Larry Lefever/Grant Heilman Photography; 610 (l), Art Wolfe; 610 (r), © Toru Yamanaka/AFP/CORBIS; 611 (b), Gamma-Liaison/Getty News Images; 611 (t), Huntsville Times

Chapter Twenty One 612-613 (t), © Stuart Westmorland/CORBIS; 614 (bl), James Beveridge/Visuals Unlimited; 614 (tc), © Gail Shumway/Getty Images/FPG International; 614 (br), Doug Wechsler/Animals Animals; 616 (l), Ken Lucas; 616 (r), John Cancalosi/Tom Stack & Associates; 617 (cl), © SuperStock; 617 (bl), © Martin Ruegner/Alamy Photos; 617 (br), © James D. Watt/Stephen Frink Collection/Alamy Photos; 617 (tl), © Ron Kimball/Ron Kimball Stock; 617 (tr), © Carl & Ann Purcell/ CORBIS; 617 (cr), © Martin B. Withers; Frank Lane Picture Agency/CORBIS; 618 (tr), Illustration by Carl Buell, and taken from http://www.neoucom.edu/Depts/Anat/ Pakicetid.html. ; 618 (tl), Courtesy of Research Casting International; 618 (b), Courtesy of Research Casting International; 619 (t), © 1998 Philip Gingerich/Courtesy of the Museum of Paleontology, The University of Michigan; 619 (c), Courtesy of Betsy Webb, Pratt Museum, Homer, Alaska; 619 (b), Courtesy of Betsy Webb, Pratt Museum, Homer, Alaska; 621 (b), Visuals Unlimited/H.W. Robison; 621 (t), James Beveridge/Visuals Unlimited; 622 (l), Christopher Ralling; 622 (r), © William E. Ferguson; 624 (b), Carolyn A. McKeone/Photo Researchers, Inc. ; 628 (b), Getty Images/Stone; 631 (r), Zig Leszczynski/Animals Animals/Earth Scenes; 631 (l), Gary Mezaros/Visuals Unlimited; 633 Victoria Smith/HRW; 634 (t), James Beveridge/Visuals Unlimited; 635 Courtesy of Betsy Webb, Pratt Museum, Homer, Alaska; 638 (l), Doug Wilson/Westlight; 639 (r), Wally Emerson/Courtesy of Raymond Pierotti; 639 (l), George D. Lepp/Photo Researchers, Inc.

Lab 643 (tr), Victoria Smith/HRW, Courtesy of Science Stuff, Austin, TX; 643, (galena), Ken Lucas/Visuals Unlimited Inc.; 643 (cr), Charlie Winters/HRW; 643, 644, 645 (hematite, br), Sam Dudgeon/HRW; 646 (all), Andy Christiansen/HRW; 647, Sam Dudgeon/HRW; 651, 652, Sam Dudgeon/HRW; 653, Andy Christiansen/HRW; 655 (tr), 657, Sam Dudgeon/HRW; 656, 657, Sam Dudgeon/HRW; 658, 659, 660, Sam Dudgeon/HRW; 662, NASA/Getty Images/Stone; 663, Sam Dudgeon/HRW; ; 689 Sam Dudgeon/HRW; 690 Sam Dudgeon/HRW; 696 (t), Peter Van Steen/HRW

Copyright © by Holt, Rinehart and Winston. All rights reserved.